
Geo Duffield

AN

# INTRODUCTION

TO

# NATURAL PHILOSOPHY.

VOL. II.

AN

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TO

# NATURAL PHILOSOPHY.

ILLUSTRATED WITH COPPER PLATES.

*By WILLIAM NICHOLSON.*

Non enim me cuiquám mancipavi, nullius nomen fero: multum magnorum virorum judicio credo, aliquid et meo vindico. Nam illi quoque, non inventa, ſed quærenda, nobis reliquerunt. SENECA.

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# CONTENTS.

## Book II. Sect. III. *Of Fluids.*



## Book II. Sect. IV. *Of the Air or Atmosphere.*

## Book III. Sect. I. *Of Chemistry.*



## Book III. Sect. II. *Of Magnetism.*



## Book III. Sect. III. *Concerning Electricity.*

BOOK III. SECT. IV. *Concerning Galvanism.*

# ERRATA TO VOL. II.

| Page | Line | | | | |
|---|---|---|---|---|---|
| 29 | 13 | *for* | in | *read* | into |
| | 6 f. bot. | — | ſound | — | found |
| 30 | 5 f. b. | — | $\frac{1}{4}$ | — | 1.4 |
| 33 | 2 | — | A B | — | a B |
| | 6 | — | it ſprings | — | its ſpring |
| 38 | 12 | — | $\frac{29565}{30}$ & $\frac{28770}{30}$ | — | $\frac{29.565}{30}$ & $\frac{28.770}{30}$ |
| 40 | 8 f. b. | — | baromer | — | barometer |
| 49 | 2 f. b. | — | A S | — | A *s* |
| 79 | 12 | — | B | — | A |
| 82 | 16 | — | G X | — | G H |
| 100 | 5 f. b. | — | too | — | two |
| 144 | 5 f. b. | — | ammonia | — | of ammonia |
| 149 | 3 f. b. | | | | |
| 151 | 3 f. b. | — | gareous | — | gazeous |
| 152 | 14, 15 | | | | |
| 154 | 14 | — | phoſphorus | — | phoſphoreous |
| 165 | 7 | | | | |
| 160 | 14 | *dele* | (170, Z.) | | |
| 161 | 6 | — | (152, X.) | | |
| | 10 | — | (152, W. 167, Q.) | | |
| 162 | 10, 11 | *for* | (17, W.) | *read* | (16, V.) |
| | 7 f. b. | — | for oxigen | — | for the oxigen |
| 165 | 8 | *dele* | (192, V.) | | |
| 168 | 5 | *for* | (231, Y.) | *read* | (160, Y.) |
| 170 | note | — | Phiſique | — | Phyſique |
| 171 | 6 | — | the metals | — | the other metals |
| | 16 | — | which | — | and. |
| 174 | 8 | — | (243, R. 182, G.) | — | (172, Q.) |
| | 11 | — | fulminating | — | a fulminating |
| 175 | 3 | — | (245, Y.) | — | (173, Y.) |
| | 8 f. b. | | | | |
| 176 | 4 f. b. | *put* | K *in the margin* | | |
| 178 | 10 | *for* | (236, R.) | *read* | (164, R.) |
| 181 | 13 f. b. | *dele* | (178, W.) | | |
| | 9 f. b. | *for* | (250, T.) | *read* | (180, T.) |
| | 5 f. b. | — | (236, R.) | — | (164, R.) |
| | ult. | — | (235, Q.) | — | (163, Q.) |
| 182 | 8 | *dele* | (178, V.) | | |
| | 8 f. b. | *for* | impropely | *read* | improperly |
| | 4 f. b. | *dele* | (217, Z.) | | |
| 186 | 11 f. b. | *for* | (251, V.) | *read* | (180, V.) |
| 223 | ult. | *dele* | if | | |
| 224 | 3 | *for* | A | *read* | *a* |
| | 2 f. b. | | | | |

AN

# INTRODUCTION

TO

# NATURAL PHILOSOPHY.

## BOOK II.

## SECT. III.

## Of Fluids.

### CHAP. I.

### OF HYDROSTATICS; OR THE EFFECTS WHICH ARISE FROM THE GRAVITY OF FLUIDS.

A FLUID is a body whose parts readily yield to any impression, and in yielding, are easily moved amongst each other. A

The cause of fluidity is not perfectly known. Some are of opinion that the particles of fluids are spherical, and, in consequence of their touching each other in few points, cohere very slightly, and easily slip or slide over each other. But that the particles of fluids are of the same nature or figure B

as thoſe of ſolids, ſeems probable, from the very frequent converſion of the one into the other. It does not ſeem rational to ſuppoſe that the particles of gold, lead, glaſs, &c. when in fuſion, are rendered ſpherical by the action of the fire, and when that action ceaſes, that the particles reſume their former figure, as the bodies become ſolid by cooling. Neither can we eaſily imagine, that the particles of water are changed by cold, when it becomes a ſolid and brittle lump of ice, and are again reinſtated in their original form, when the ice, by diſſolution, is again turned to water.

C The original cauſe of fluidity, then, does not appear to conſiſt in the figure of the particles, but ſimply in their want of coheſion.

D If the particles of a body cohere ſtrongly together, it is evident that they will not eaſily move amongſt each other. An imperfect coheſion muſt therefore be one of the properties of a fluid maſs; and that the ſmallneſs of the particles is requiſite to fluidity, will appear by conſidering, that the ſurface of a body compoſed of ſmall particles muſt be much more ſmooth and even than the ſurface of a body compoſed of larger particles: that two flat bodies may be conceived to conſiſt of particles ſo ſmall that their ſurfaces ſhall differ inſenſibly from perfect planes: that theſe bodies, if placed on each other, will ſlide without the leaſt ſenſible friction: and that if the particles of theſe bodies thus placed on each other be, by any means, deprived of the whole, or the greateſt part of their coheſion, the

bodies will not only ſlide on each other in the juſt mentioned plane, but the parts of the maſs will alſo ſlide on each other in any other direction whatſoever. Conſequently they will readily yield to any impreſſion, and in yielding, be eaſily moved amongſt each other; that is, they will conſtitute a fluid maſs.

But the inquiry, wherein conſiſts that change E
which bodies undergo when their conſiſtency is altered ſo as to make them aſſume a fluid form, either denſe and almoſt incompreſſible, or vaporous and elaſtic, belongs not to this place, but to chemiſtry.

That ſcience, which treats of the effects ariſing F
from the weight of fluids, is called hydroſtatics.

The parts of fluids are heavy; but becauſe the G
upper parts reſt upon, and are ſuſtained by, the parts beneath, and becauſe, by the property of fluids, the parts are readily moved in all directions, upwards as well as downwards, they do not at firſt conſideration appear to be heavy.

The bottom of an upright priſmical or cylin- H
drical veſſel is preſſed by the whole weight of the fluid contained; and as the weight of the fluid is in proportion to its height, ſo is likewiſe the preſſure. Thus, in the cylinder A B (fig. 114) when filled to C, the bottom is preſſed by, or ſuſtains, a certain weight, ſuppoſe one pound; if it be filled to D, the preſſure becomes two pounds; if to A, three pounds, &c. the heights between B, C, D, and A being ſuppoſed equal.

The whole of any fluid maſs may be imagined to I
conſiſt of a number of columns of an inconſiderable

thickneſs, which ſtand perpendicularly on the baſe of the containing veſſel, and preſs the ſame with their reſpective weights. The preſſure, then, if the height remain the ſame, is as the number of columns, and this number is as the area of the

K baſe. Conſequently in veſſels whoſe baſes differ as to area, and which contain fluids of the ſame denſity, but different heights, the preſſure will be in the compound ratio of the baſes and heights; that is, in numbers, as the area of the baſe multiplied by the height of the fluid in one veſſel, is to the area of the baſe multiplied by the height of the fluid in the other veſſel, ſo is the preſſure ſuſtained by the baſe of the one to the preſſure ſuſtained by the baſe of the other veſſel.

L In like ſituations, the preſſures of fluids will be as their denſities.

M The denſities being diſcoverable moſt readily by the different weights of bodies of the ſame bulk, the comparative denſities of bodies are therefore called their ſpecific gravities.

N If the columns of which a fluid maſs was ſuppoſed to conſiſt (3, 1) were formed of particles lying in perpendicular right lines, the preſſure of the fluid would be exerted on the bottom of the veſſel only; but, as they are ſituated in every irregular poſition, there muſt, of conſequence, be a preſſure exerted in every direction; which preſſure muſt be equal at equal depths. For if any part of the whole maſs were not equally preſſed on all ſides, it would move towards the ſide on which

which the preſſure was leaſt; and would not become quieſcent till ſuch equal preſſure was obtained. The quieſcence of the parts of fluids is therefore a proof that they are equally preſſed on all ſides.

On this account it is, that fluids, as far as they O
are not prevented by external accidents, always conform their upper ſurface to the plane of the horizon. For if any column or part of the fluid be elevated above the reſt, it will deſcend partly by ſinking into the fluid, and partly by its lateral preſſure, that will cauſe it to ſpread ſideways over the ſurface, till it becomes uniformly of the ſame height, or horizontal.

The equal preſſure of fluids in every direction, P
being underſtood, may be applied to account for many phenomena that happen to them in different circumſtances; ſome of which are the following:

The horizontal bottom of a veſſel is preſſed by, Q
and ſuſtains no more nor leſs than the weight of a column of the fluid it contains, whoſe baſe is the bottom itſelf, and whoſe height is that of the fluid.

In the veſſel E C D F (fig. 115) the bottom C D R
ſuſtains no more than the column A B D C. For the other parts of the contained fluid can only preſs the column A B D C laterally, and therefore contribute not at all to the increaſe of the weight or preſſure on the bottom C D; but reſt entirely on the ſides E C and F D.

Alſo in the veſſel E C D F (fig. 116), the bottom S
E F ſuſtains a preſſure equal to the weight of a column whoſe baſe is E F, and height equal to C A.

For the pressure at A B is equal to the weight of the column A B D C, and its lateral pressure, which is equal to the same weight, must cause the parts between E A and B F to press the bottom with an equal force in proportion to the surfaces they cover. Consequently, the effect will be the same as if the whole fluid were of the height C A.

T. From these two cases combined, the reason is evident, why fluids contained in the several parts of vessels (fig. 117), remain every where at the same height. For the lowest part where they communicate, may be regarded as the common base; and the fluids, which rest thereon, are in equilibrio then only, when their heights are equal, however their quantities may vary.

U The hydrostatical paradox, as by some it is called, depends on the equal pressure of the parts of fluids every where at the same depth. It is this:

V Any quantity of fluid, however small, may be made to counterpoise and sustain any weight, how large soever.

W Let A B E G (fig. 118) represent a cylindrical vessel, to the inside of which is fitted the cover C, which by means of leather at the edge, will easily slide up and down in the internal cavity, without permitting any water to pass between it and the surface of the cylinder. In the cover is inserted the small tube C F, open at top, and communicating with the inside of the cylinder beneath the cover at C. The cylinder is filled with water, and the cover put on. Then, if the cover be loaded with

with the weight, suppose of a pound, it will be depressed, the water will rise in the tube to E, and the weight will be sustained. If another pound be added, the water will rise through an equal space to F, and the weight will be sustained, and so forth, according to the weight added, and the length of the tube. Now, the weight of the water in the tube is but a few grains; yet its lateral pressure serves to sustain as much as the weight of a column of water, whose base is equal to that of the cylinder, and height equal to that in the tube. Thus, the column E C produces a pressure in the water contained in the cylinder, equal to what would have been produced by the column A a d D; and, as this pressure is exerted every way equally, the cover will be pressed upwards with a force equal to the weight of A a d D: consequently, if A a d D would weigh a pound, E C will sustain a pound: and the like is true of other heights and weights. And by diminishing the diameter of the tube, any quantity of water, how small soever, will, in theory, sustain any weight, however large.

The same may be shewn more simply thus:

Let A G H D (fig. 119) represent a hollow cylinder, and M N a cylinder of wood, which nearly fills its cavity. In the cylinder, suppose a little water, whose surface is g b; then, if the wooden cylinder be put into the hollow one, the water will rise between the surfaces to a and d, and the wood will be sustained floating. The nearer the wooden cylinder approaches to the size of the cavity, the less water is necessary for the experiment.

## CHAP. II.

### CONCERNING BODIES IMMERSED IN FLUIDS, AND THE METHODS OF FINDING SPECIFIC GRAVITIES.

Y IF a solid body be plunged in a fluid, it will be pressed on all sides, but not equally. Let D B E C (fig. 120) represent a solid prismatic body, immersed, with its axis vertical, in the fluid contained in the vessel F G I H, then the sides D C and B E will be equally pressed; the upper surface D B will be pressed with the weight of a column, whose base is D B, and height A D, and the under surface will be pressed upwards with a force equal to the weight of a column whose height is A C (4, N). The body will therefore be impelled upwards by a force equal to the excess of A C above A D; that is, equivalent to the weight of a column of the fluid whose length is D C, the base being all along supposed to
z be unvaried. Whence it appears, that every prism, whose axis is perpendicular to the horizon, will, if it be totally immersed in any fluid, be impelled upwards by a force, which is equal to the weight of a quantity of the fluid of the same bulk with the prism. And since any solid whatsoever may be conceived to be formed of an indefinite number of such prisms, it is evident that the rule is true of all bodies, without respect to figure.

But

But as all bodies, by the force of gravity, tend B downwards, it depends upon the abſolute weight of the immerſed body, whether it ſhall aſcend or deſcend. If the weight of the body exceed that of an equal bulk of the fluid, the exceſs of force tends downwards, and it will deſcend; but, on the contrary, if the weight of the body be leſs than that of an equal bulk of the fluid, the above-mentioned preſſure will prevail, and it will aſcend; if both be preciſely equal, the body will remain at reſt any where in the fluid.

Theſe things being conſidered, it appears that C any body, how heavy ſoever, may be made to ſwim, or any body, how light ſoever, to ſink, if means be uſed to keep off the preſſure of the fluid from the one or other ſide, as circumſtances require: for if ADBK be ſuppoſed to repreſent an open D tube, inſtead of a column of the fluid, and the body DBCE be applied cloſely to its lower orifice, ſo that the fluid may not enter the tube, the preſſure on DB will be taken off, and conſequently the body will be preſſed upwards with a force equal to the whole column AC. If that column be of ſufficient length, that is, if the body be immerſed ſufficiently deep, the preſſure will exceed the gravity of the body, and therefore ſuſtain it. In the ſame manner, if M be a body applied to the open E end of a tube, which is cloſed at N, the inferior preſſure being taken off, the body will not riſe, however light, but remain immerſed, by means of the preſſure on the ſuperior ſurface.

When

When a body floats at the surface of a fluid, the quantity of the fluid, displaced by the part immersed, is equal in weight to the floating body. For since the body presses downwards with its whole weight, it must sink till the pressure, which the fluid exerts upwards, is equal to that weight. In this situation, suppose the fluid to be congealed, and the solid then removed: a cavity will be left in the fluid corresponding in form and magnitude with the immersed part of the solid. Imagine this cavity be filled with a quantity of the same fluid, so that its surface may be level with the rest, and the whole fluid then thawed. The fluid which occupies the place of the solid will then be pressed upwards with a force equal to that sustained before by the solid, namely, equal to the weight of the solid. But it is not moved by that force, for the surface must continue level (5, 0), as before the thaw. The last mentioned quantity of fluid must therefore press downwards with an equal force. That is to say, the weight of a quantity of fluid equal in bulk to the immersed part of a solid which floats on its surface, is equal to the whole weight of the solid.

By the same argument, it follows, that if a floating body be loaded with weights, so as to cause it to sink deeper in the fluid, the additional parts immersed will in bulk be equal to, or displace, parts of the fluid, whose weights are equal to those the floating body was loaded with.

Since

Since bodies of equal bulks will lose the same quantity of absolute weight when immersed in fluids of equal density, it follows obviously, that the bulks of bodies are in proportion to the loss of weight they sustain by immersion in a given fluid. Whence we have an exact method of determining the bulks of bodies whose weights are known, and from thence finding their specific gravities. For, H

As the bulk of one body, or the weight it loses by immersion,

Is to its mass of matter, or absolute weight,

So is the bulk of any other body, or the weight it loses by immersion,

To the mass of matter, or absolute weight, it would have had if of the same specific gravity with the first body. Which weight last found being compared with the real weight of the latter body, shews the proportion of their specific gravities.

For example: if 34 oz. of lead be weighed in water, and the diminution be 3 oz.; and 15 oz. of tin be also weighed in water, and the diminution appear 2 oz.; it is required to determine the proportion of their specific gravities. For which purpose, I

As the diminution in the lead 3, is to its weight 34, so is the diminution in the tin 2, to the weight of a mass of lead of the same bulk $22\frac{2}{3}$ oz. which is to 15 as the specific gravity of lead is to that of tin, that is to say, in lower terms, nearly as $11\frac{1}{3}$ to $7\frac{1}{2}$. K

But

L But it is more usual and convenient to make rain-water the standard, and refer the other substances to it: thus, in the instances just mentioned, the weight of a mass of water equal in bulk to the lead is 3 oz.: lead is therefore to water as 34 to 3, or as $11\frac{1}{3}$ to 1; and in like manner, tin is to water as 15 to 2, or as $7\frac{1}{2}$ to 1.

M When the solid is lighter than the fluid in which it is weighed, an additional body of greater density may be joined to it: for instance, suppose a piece of cedar-wood, weighing 92 dwts. were required to be weighed; join to it, by means of a small hair or thread, a piece of lead, whose weight in water is known, and weigh them immersed together. The lead will then appear to weigh less by 58 dwts. than it did without the addition of the cedar; from whence it is evident that the cedar is impelled upwards by a force that exceeds its own weight by that quantity, or in other words, that a quantity of water equal in bulk to the cedar, will weigh $92 + 58$, or 150 dwts.; consequently the specific gravities of water and cedar are in proportion as 150 to 92, or in lower terms, as 1 to $\frac{6}{10}$ nearly.

N In this experiment it is necessary first to smear the wood lightly with some fat substance, otherwise the water will be imbibed by the wood, and will render it specifically heavier than before. In fact, wood is not specifically lighter than water, but by means of the air-vessels which run through its substance.

The

The beſt method to diſcover the ſpecific gravities of fluids is, to weigh the ſame ſubſtance in different fluids; and becauſe the diminution it ſuffers in weight is equal to the weight of a quantity of the fluid of the ſame bulk, we thence obtain the weights of equal quantities of different fluids, and the ſpecific gravities are as thoſe weights; thus, if a piece of glaſs weighed in the concentrated acid called oil of vitriol, loſe 85 grs. and when weighed in water only 40 grs. their ſpecific gravities will be as thoſe numbers, or in lower terms, as $21\frac{1}{4}$ to 10. o

The hydrometer, or inſtrument uſually applied to find the ſpecific gravities of liquids, is conſtructed as follows: A B (fig. 121) is a tube of glaſs, joined to a hollow ball C, at the bottom of which is a ſmaller ball D. In the cavity D is placed a quantity of quickſilver, by which the inſtrument is ſo poiſed, that it ſwims in proof ſpirits of wine immerſed to the point M. A quantity of proof ſpirits equal in weight to the whole inſtrument, will therefore be equal in bulk to the immerſed part (10, F). If it be immerſed in another liquid, whoſe ſpecific gravity is greater, it will ſwim with the tube higher out of the water, ſuppoſe to the point B. Then the weights of the quantities diſplaced remaining the ſame, their bulks will be as the immerſed parts of the hydrometer, and the ſpecific gravities of the fluids will be inverſely as thoſe bulks. The proportion which any length of the tube bears to P

the

the whole bulk of the inſtrument being known, it will not be difficult to graduate the tube ſo as to indicate the ſpecific gravities by inſpection. But this, however, is ſcarcely ever done.

Q This inſtrument is very confined in its uſe. For if the liquors differ conſiderably in ſpecific gravity, they exceed the limits of the graduation: thus, the hydrometer, adapted for ſpirits, will ſwim in water with part of the ball above the ſurface; and if it be adapted to water, it will not ſwim in ſpirits at all. It is true, this may be remedied, either by lengthening or widening the tube: but the firſt is inconvenient, and the latter would make the graduations ſo ſhort, as to render them of little uſe.

R To make this inſtrument of more ſervice, there has been added a little plate or diſh D D (fig. 122) at the top of the tube, upon which may be placed weights, as convenience requires. For example, if the whole inſtrument float immerged in ſpirits to the point M, it will require an additional weight to ſink it to the ſame depth in water. Suppoſe the inſtrument to weigh 10 dwts. and to be adjuſted to rectified ſpirits of wine, it will then require the addition $1\frac{6}{10}$ dwt. to ſink it to the ſame point in water. Conſequently it appears, that the ſpecific gravity of water is to that of ſpirits of wine as $11\frac{6}{10}$ to 10, or in lower terms, as 1 to $\frac{86}{100}$.

S This is the beſt hydrometer, both in reſpect to exactneſs and facility in practice. The inſtrument uſed by the officers of Exciſe, is very well adapted for

for its purpose, which is more confined: it differs from that here described, by having its additional weights screwed on at a stem at E. These instruments are usually of copper.

An attempt has been made * to adapt the hydrometer to the general purpose of finding the specific gravity, both of solids and fluids (fig. 123). A is a hollow ball of copper; B is a dish affixed to the ball by a short slender stem D; C is another dish affixed to the opposite side of the ball by a kind of stirrup. In the instrument actually made, the stem D is of hardened steel, $\frac{1}{40}$ of an inch in diameter, and the dish C is so heavy as in all cases to keep the stem vertical, when the instrument is made to float in any liquid. The parts are so adjusted that the addition of 1000 grains, in the upper dish B, will just sink it in distilled water, at the temperature of 60° of Fahrenheit's thermometer, so that the surface shall intersect the middle of the stem D. Let it now be required to find the specific gravity of any fluid. Immerse the instrument therein, and by placing weights in the dish B cause it to float, so that the middle of its stem D shall be cut by the surface of the fluid. Then, as the known weight of the instrument added to 1000 grains; is to the same known weight added to the weights used in producing the last equilibrium: so is the weight of a quantity of distilled water displaced by the floating instrument; to the weight of an equal bulk of the fluid under

* By the author of this work.

consideration.

consideration. And these weights give the ratio of the specific gravities (4, M). Again, let it be required, to find the specific gravity of a solid body less than 1000 grains. Place the instrument in distilled water, and put the body in the dish B. Make the adjustment of sinking the instrument to the middle of the stem, by adding weights in the same dish. Take those weights from 1000 grains, and the remainder will be the weight of the body. Place now the body in the lower dish C, and add more weight in the upper dish B, till the adjustment is again obtained. The weight last added will be the loss the solid sustains (8. Z, A) by immersion, and is the weight of an equal bulk of water. Consequently the specific gravity of the solid compared with water, is as its weight to the loss it sustains by immersion.

U This instrument was found to be sufficiently accurate to give weights true to less than one twentieth of a grain.

V Experiments concerning specific gravities are more difficult to be made with accuracy than authors in general seem to imagine. For we often see tables of specific gravities carried to four, five, and even six places of figures; whereas a difference of a few degrees in the temperature of the water will change the fourth figure. In different specimens of the same wood, the specific gravities will vary in the third figure, as will also metals cast out of the same melting, but cooled more quickly or slowly; and these also are alterable by hammer-

ing

ing *. Natural and artificial compounds have likewise great varieties of density in the several specimens denoted by the same name.

A Table of Specific Gravities, extracted from various Authors.

| Names. | Authors. | Sp. Gravity. |
|---|---|---|
| Platina | Kirwan | 23.000 |
| Gold | Muschenbroek | 19.238 to 19.640 |
| Gold standard of George II. | Muschenbroek | 17.150 |
| Silver | Kirwan, Muschenb. | 11.091 |
| Copper | Kirwan | 8.7 to 9.300 |
| Steel soft | Muschenb. | 7.738 to 7.8955 |
| Steel elastic | Muschenbroek | 7.809 |
| Iron bar | Muschenbroek | 7.60 to 7.875 |
| Lead | Muschenbroek | 11.226 to 11.479 |
| Tin | Muschenbroek | 7.000 to 7.450 |
| Mercury | Muschenbroek | 13.55 to 14.110 |
| Zink | Kirwan | 6.9 to 7.24 |
| Regulus of antimony | Kirwan | 6.860 |
| Regulus of arsenic | Kirwan | 8.310 |
| Bismuth | Kirwan | 9.6 to 9.7 |
| Cobalt, the regulus | Kirwan | 7.7 |
| Nickel | Kirwan | 7.421 to 9.000 |
| Regulus of manganese | Kirwan | 6.850 |
| Wolfram, the regulus † | De Luyart | 17.6 |
| Common brimstone | Muschenbroek | 1.8 |
| Fine glass | Muschenbroek | 3.150 to 3.380 |
| Plate glass | Muschenbroek | 2.888 |
| Plate glass | B. Martin | 2.76 |
| Green glass for retorts, &c. | Muschenbroek | 2.620 |

* Experiments frequently repeated by the Author have shewn the specific gravity of two nearly equal smooth cylinders of lead, cast out of the same fusion were to each other as 1138 to 1125.

† A chemical analysis of wolfram. London, 1785.

| Names. | Authors. | Sp. Gravity. |
|---|---|---|
| Crown glass - - | B. Martin - | 2.52 |
| White flint - - - | B. Martin - | 3.29 |
| White flint - - - | - - | 3.216 |
| Dense glass for achromatic uses - - - | - - | 3.437 |
| The concave of an achromatic lens - - | - - | 3.436 |
| Calcareous spar (calx aerata) from the same piece - | - | 2.711 to 2.720 |
| Ponderous spar or barytes vitriolata - - | - - | 4.474 |
| Quartz - - - | Muschenbroek - | 2.763 |
| Rock crystal - - | Muschenbroek - | 2.650 |
| Diamond - - | Muschenbroek | 3.466 to 3.654 |
| Rain-water - - | - - | 1.000 |
| Distilled water - | Muschenbroek - | 0.993 |
| River water - - | Muschenbroek - | 1.009 |
| Sea water - - | Muschenbroek - | 1.030 |
| Saturate solution of sea-salt | Muschenbroek - | 1.244 |
| Concentrated vitriolic acid | Bergman - | 2.125 |
| Concentrated nitrous acid | Bergman - | 1.580 |
| Concentrated muriatic acid | Bergman - | 1.150 |
| Concentrated fluor acid - | Bergman - | 1.500 |
| Oil of amber - - | Muschenbroek - | 0.978 |
| Oil of sweet almonds - | Muschenbroek - | 0.928 |
| Oil of Olives - - | Muschenbroek - | 0.913 |
| Naptha - - | Muschenbroek - | 0.708 |
| Rectified spirit of wine - | Muschenbroek - | 0.866 |
| Alcohol - - | Muschenbroek - | 0.815 |
| Ether - - | Muschenbroek - | 0.732 |
| Air at the earth's surface | Muschenb. | $0.001\frac{1}{3}$ to $0.001\frac{1}{4}$ |
| Air. Barometer at 30 In. Thermometer 32° - | Atwood - | 0.001279 |

CHAP.

# CHAP. III.

## OF THE MOTION OF FLUIDS WHICH ARISES FROM THE PRESSURE OF THEIR SUPERINCUMBENT PARTS.

The pressure of fluids being shewn to be in proportion to their depths (39 H) it will not be difficult to find the celerities with which they spout forth from small apertures in the sides or bottoms of vessels.

For this purpose let us suppose P Q S R (fig. 120) to be a prismical column of any fluid that passes through a hole in the bottom of the vessel F H h G. If the height P Q be assumed indefinitely small, the pressure by which the velocity is produced may be esteemed constant, because the column O P R V, whose weight (5, Q) is the measure of that pressure, does not acquire any definite increase during the passage of the column through its height P Q. The weight of the column O P R V exceeds the weight of the column P Q S R in the same proportion as the height P O exceeds the height P Q, and consequently the action or pressure exerted on the column P Q S R exceeds its mere gravity in the same proportion. Therefore, whatever may be the final velocity, or velocity of emission, produced in the column P Q S R in passing through P Q, it will be required, in order to produce an equal final velocity by the mere action of gravity, that the same

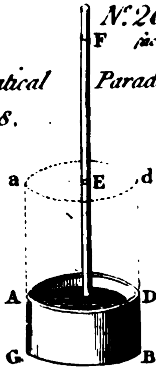
column ſhould deſcend through a ſpace propor-tionably greater as this laſt is leſs than the former force (1. 36, H), namely through a ſpace equal to
Y PO. That is to ſay, the velocity of any fluid iſſuing from a hole in the bottom of a veſſel is equal to that which would be acquired by a body falling freely by its gravity through a ſpace equal to the perpendicular height of the fluid above the hole.

Z And becauſe fluids preſs equally every way at equal depths (4, N), this theorem holds good likewiſe with reſpect to fluids that ſpout through apertures at the ſides of veſſels, or with any obliquity whatſoever.

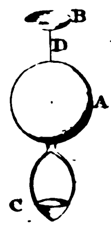
A Hence the motions of ſpouting fluids may be reduced to rule. For every part of the projected ſtream being conſidered as a body in motion, thrown with a given velocity and direction, the ſame principles will be equally applicable to ſpouting
B fluids and to projectiles of any other kind. Thus if the fluid ſpout directly downwards, its velocity in any point of its courſe will be equal to the velocity of emiſſion added to that which it would have acquired by gravity in its fall from the aperture; or, (20, Y) which is the ſame thing, its velocity will be the ſame as if it had fallen from the ſurface of the fluid. If it ſpout directly upwards, it will (1. 31, P. II. 20, Y) proceed with an uniformly retarded motion, which will carry it to the level of the ſurface of the fluid in the veſſel. If it ſpouts in any other direction, its courſe will be nearly a parabola (1. 97, V).

Fluids.

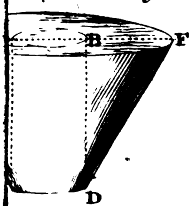

Hydrostatical Paradox.
Fig. 118.



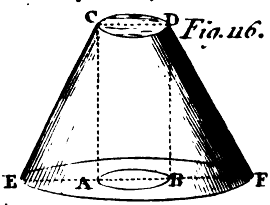

Hydrostatic Instrument
Fig. 123.




of Fluids Fig. 115.

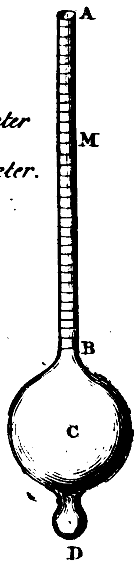



Pressure of Fluids
Fig. 116.

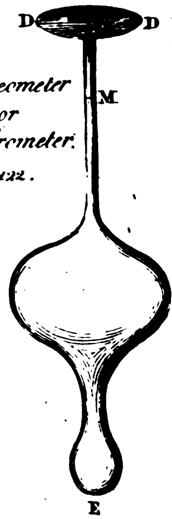




Areometer
or
Hydrometer.
Fig. 121.




Areometer
or
Hydrometer.
Fig. 122.



On these considerations depends the performance c
of fountains: for the construction of which there is provided a reservoir, elevated considerably above the plane in which the fountain is to be made. A pipe, communicating with the reservoir, is conveyed to the middle of a bason, and by means of a perpendicular spout, called the adjutage, throws the water up in the air to a height which is in the level of the surface of the water in the reservoir.

But in applying these observations to practice, D
there are many circumstances that tend to diminish the quantities of motion. There are few fluids that have not a considerable degree of cohesion or tenacity, which prevents their parts from moving as freely as otherwise they would have done; and the friction against the sides of tubes very much retards the motion of the included fluids, if the tubes be long, small or crooked, and the velocity great. The air which, extricating itself from the water, occupies the upper parts of bent pipes, is often a great obstacle to the course of the water, and not unfrequently stops its progress entirely. In fountains, especially where the fluid is thrown perpendicularly upwards, the part that is falling rests upon the ascending column, and prevents its arriving at the height its motion would have carried it to; besides which, the resistance of the air, and other causes, join in increasing the same effect. We must not therefore expect, in these more than in other engines, that the per-

formance will equal the theory; yet, it is not difficult to make the proper allowances, so as to find their real effects by calculation; but our purpose, being general, does not extend to the variety of particulars which offer themselves.

## CHAP. IV.

### OF THE RESISTANCE WHICH FLUIDS MAKE TO BODIES MOVING IN THEM.

E WHEN a body is immersed in a mass or quantity of fluid matter, and is in motion, it must separate the parts of the fluid from each other as it moves. If the parts of this fluid be without cohesion or tenacity, this separation will be attended with no difficulty; but if the tenacity be considerable, it will require a considerable force to overcome it. A part of the motion must therefore be lost in producing this effect. And, in the same fluid, the more parts are divided in a given time, the greater quantity of the motion must be lost or employed for that purpose. But a body, moving through an uniform fluid, divides a greater or less number of its parts, in proportion as the velocity of its motion is greater or less.
F Consequently, the resistance which an uniform fluid makes, by reason of its tenacity, to a body immersed and moving in it, is in proportion to the velocity of the moving body.

But

But there is another resistance of greater consequence, which fluids make to bodies immersed and moving in them, and arises from the inertia of their parts. For if a body be moved in a fluid, it must give motion to a certain quantity of that fluid, and the reaction of that quantity will destroy part of the motion of the body. Now a body moving through an uniform fluid, gives motion to a greater or less number of its parts, in proportion to the velocity of its motion, and is therefore resisted in the simple proportion of the velocity on that account. Again, a body moving through an uniform fluid, communicates a greater or less quantity of motion to each of its parts, in proportion to the velocity of its motion, and is therefore resisted in the simple proportion of the velocity on that account. On both accounts, then, the resistance which arises from the inertia of the fluid, is in the duplicate proportion of the velocity of the moving body.

When the same body is spoken of, the resistance and retardation follow the same ratio; but, in different bodies, they differ in the same manner as motion and velocity. Resistance signifies the quantity of motion, and retardation the quantity of velocity, which is destroyed; for example, if a body be projected with a given velocity in a fluid, and lose half its motion by the resistance in a given time, its retardation will be half its velocity: but if another body of the same bulk, but twice the weight or mass of matter, be projected with a like

like velocity in the same fluid, it will be equally resisted; but, having twice the quantity of motion, will only lose one-fourth of its velocity in the same time. Thus, though the resistances be equal, the retardation in the latter instance is only half the quantity of that in the former.

K In fluids that are not glutinous, the resistance arising from their tenacity is inconsiderable; especially in swift motion; in which case, the resistance from the inertia increasing as the squares of the velocities, while that from the tenacity increases only as the velocities themselves, the proportion of the latter to the former becomes so small that it may be neglected. It is usual therefore, to neglect that resistance which arises from the tenacity of fluids.

L In like circumstances, the resistances of fluids are as their densities. For the quantity of matter to be moved is in that proportion.

M If a cylinder be moved through an uniform fluid in the direction of its axis, it will suffer a resistance equal to that of a sphere, whose diameter and velocity of motion in the same fluid are equal to those of the cylinder. For proof of which, suppose the cylinder to be quiescent in the middle of a prismical canal or tube, its axis coinciding with that of the tube. Let this tube be filled with the fluid, and conceive the fluid to be moved through it with a given velocity. Then the fluid will pass between the sides of the tube and the cylinder, and its motion will be impeded by its being reduced to pass

through

through a narrower space. If the sphere be substituted in the place of the cylinder, the space through which the fluid is reduced to pass will be precisely the same, and consequently its motion will be equally impeded. And, because action and reaction are equal, the cylinder and sphere in these circumstances will be equally acted upon by the fluid. Now, let the fluid be supposed quiescent, and the cylinder or sphere moved with the same velocity, and in the contrary direction to that in which the fluid was before moved; and the relative motions of the fluid and immersed body will be the same as before. Consequently, the cylinder and sphere, if moved with equal velocities through a prismical vessel containing a fluid, will be equally acted upon in the contrary direction to their motions; that is, they will be equally resisted. And, since this equality of resistance does not at all depend on the magnitude of the prismical vessel, the doctrine may be applied to bodies moving in an indefinitely extended fluid, or fluid contained in an indefinitely large prismical vessel. It may, therefore, be applied to all bodies in motion which are deeply immersed in any fluid.

Hence it appears, that in order to maintain the uniform motion of a body in a fluid, a constant accession of force is required to overcome the resistance; but as, in general, there is no such accession in the motions which are performed about us, they all decay by degrees, and at length terminate.

It

O It likewise appears, that when a body moves in any fluid, and is acted upon by any constant force, it can obtain but a certain degree of velocity. For, as the resistance increases with the velocity, but in a higher proportion, namely, as the squares, (23, H) it is plain that the resistance at a certain period of the acceleration will become equal to the constantly acting force; after which the body will proceed uniformly, and the constantly acting force will be employed in overcoming the resistance. On this account it is, that bodies that sink in water, or other fluids, by the force of gravity, soon acquire their utmost velocity, and afterwards proceed uniformly. And, in like manner, a ship, when it first gets under way, proceeds with an accelerated velocity, till the resistance of the water becomes in equilibrio with the action of the wind on its sails; but afterwards proceeds uniformly; the force of the wind being entirely employed in overcoming that resistance.

P In mathematical strictness it is not true, that a body in these circumstances ever arrives at uniformity of motion; for the approach of the resistance to an equality with the impelling force is
R represented by a converging series, the number of whose terms is infinite, and their sum in any finite time is less than the impelling force: but the latter terms soon become too small to be of any physical consequence.

Q What is here said of resistance is to be understood of bodies deeply immersed in fluids, the parts

parts of which are compressed together, and non-elastic or incapable of condensation. Friction is likewise neglected. Bodies moving at or near the surfaces of fluids, more especially if they be obtuse, cause the fluid to rise into a heap before the body, at the same time that it subsides at the hinder part. And so likewise, obtuse bodies, moving in elastic fluids, condense that part of the fluid towards which they are moving, while the part from which they recede is rarefied. In these cases the resistances are greater than would be deduced by the principles here treated of *.

* Principia, II. § 8.

BOOK

# BOOK II.

## SECT. IV.

## Of the Air or Atmoſphere.

### CHAP. I.

#### OF THE GENERAL PROPERTIES OF THE AIR, THE DIMENSIONS OF THE ATMOSPHERE, AND THE MEASUREMENT OF THE HEIGHTS OF MOUNTAINS BY MEANS OF THE BAROMETER.

1 CONTINUAL experience ſhews, that we are immerſed in a fluid which agitates bodies when it is in motion; reſiſts the motions made in it; ſuſtains bodies floating in it; and, in ſhort, differs very little in its general properties from the groſſer fluids; great rarity, elaſticity, and tranſparency, being its diſtinguiſhing characters.

2 The whole maſs of this fluid, with its contents, is called the atmoſphere; a term made uſe of when the effects that ariſe from its form, magnitude, denſity, &c. are conſidered; but when the fluid of which the maſs is compoſed is indefinitely ſpoken of,

of, with a view to develope its qualities, and conſider it independent of the bodies immerſed in, or mixed with it, it is called the air, or air.

Air is a fluid, whoſe particles are not in contact, and repel each other with a force that may be diminiſhed, but cannot be deſtroyed by any degree of cold known in the vicinity of the earth. T
For, if the particles were in contact the fluid could not be compreſſed, and if they did not repel each other, the fluid could not expand when the compreſſing force is removed. This property of the U
air may be ſhewn by various methods: one of the ſimpleſt is, to pour a quantity of quickſilver in the tube A B C (fig. 124), cloſed at A, and open at C. Suppoſe the tube to be filled with quickſilver to B, then the air incloſed in the leg A B will prevent its riſing higher than D. Mark F in the ſame horizontal line with D, and (6, T) the column D B will be in equilibrio with F B; conſequently the quickſilver contained between F and D will not at all preſs on the air between A and D. But the column B F acting with its whole weight on the quickſilver between F and D cauſes it to preſs on the air at D, and condenſe it. By increaſing the quantity of quickſilver the condenſation is increaſed, and it is found, that the ſpaces into which V
the air is condenſed by different weights are inverſely as thoſe weights; or its denſity is as the preſſure it bears.

One of the firſt objects of inquiry that offer W
themſelves reſpecting the atmoſphere is its extent

or

or magnitude. Experience assures us, that it is extended over the whole surface of the earth and sea; and it is evident, from the suspension and
r motion of the clouds, that its altitude is considerable; but the measure of this altitude must be obtained from its effects. Thus, if the specific gravity of the air be found, and also its whole pressure on bodies, it will be easy to discover the quantity of the fluid, and its height, if supposed to be uniformly dense. Another method of discover-
u ing the height of the atmosphere is deduced from optical considerations, by observing the effect it has on the light of the sun.

x 18 To find the specific gravity of the air, let A B (fig. 25) represent a bottle, whose contents are exactly known; for example, suppose it capable of holding two pounds of rain-water; let a valve, opening outwards, be fitted at A, and the air be exhausted from within by means of the air-pump, hereafter to be described; let the vessel thus exhausted be weighed in water, or any other dense fluid, in the vessel M N, as represented in the figure, after which let the air be admitted. An additional weight of about $14\frac{1}{2}$ grains will be required to restore the equilibrium: therefore, the air contained
v in the vessel A B weighs $14\frac{1}{2}$ grains, the proportion of which to two pounds is 1 to 800, or $\frac{1}{4}$ to 200.

y In this experiment the vessel B is immersed in water, that the fulcrum of the scales, being less loaded, may turn with less friction, and consequently

quently be more sensible. It is attended, however, with some difficulties; the chief of which consists in the attraction or repulsion exerted at the surface of the water, and this is considerable enough to induce some philosophers to weigh the bottle without immersing it.

The specific gravity of air, being thus discovered, its pressure may be found by the Torricellian experiment, so called from its inventor Torricelli. Let A B (fig. [illegible]) represent a glass tube of the length of 35 inches or upwards, closed at the end A, and open at B; fill the same with quicksilver, and close the orifice B with the finger, or otherwise; immerse the end B in the vessel of quicksilver C D, and remove the finger from the orifice; the quicksilver will then subside to E in the tube at the height of about 30 inches.

This phenomenon is readily explained on the common principles of hydrostatics; for which purpose it must be remembered, that the pressure a body immersed in the vessel C D, would sustain, is not only that which arises from the weight of the quicksilver, but likewise from that of a column of the atmosphere incumbent on its surface; so that every column of the quicksilver presses with a force that exceeds its own weight. When the tube is inverted into the vessel of quicksilver, the surface of the column it contains being defended from the pressure of the atmosphere by the closure at A, can press downwards with no more than its own weight; and will, therefore, be in equilibrium with the pressure the

the quickſilver in the veſſel exerts againſt its deſcent, then only, when it is ſo much longer, that the additional quickſilver may be equal to the additional weight which a ſimilar column in the veſſel receives from the preſſure of the atmoſphere; that is to ſay, the preſſure of the atmoſphere on any given ſurface is equal to the weight of a column of mercury, whoſe baſe is the given ſurface, and height equal to that at which it ſtands in the Torricellian tube; and this preſſure is the weight of a column of air, whoſe baſe is the given ſurface, and height equal to that of the atmoſphere. Or, generally, becauſe the baſes may be ſuppoſed not to vary, the preſſure of the atmoſphere, is as the height of the mercury in the tube.

An inſtrument conſiſting of a Torricellian tube, with a ſcale adapted for meaſuring the heights of the mercury, is called a Barometer.

It has been ſhewn, that when the air is condenſed, its denſity is in proportion to the weight that compreſſes it (29, U). By means of the Torricellian tube it may be obſerved, that the ſame proportion obtains when it is rarefied by taking off part of the weight of the ſuperincumbent atmoſphere. For, in any elaſtic fluid at reſt, the ſpring muſt equal the compreſſing force (1. 22, R); and if any part of that force be taken away, it muſt expand till the ſpring becomes equal to the remainder; which will happen if the elaſticity of the fluid be weakened by expanſion. And ſince the preſſures of fluids are as their heights (3, H) the

the pressure of the mercury in the tube A B (fig. 126) will be equal to that in the tube A B, when the mercury rests at n in the same horizontal line with N. Now, if a bubble or small quantity of air be admitted into the tube A B, it will depress the mercury below the mark N, till its spring, and the weight of the mercury remaining in the tube, be in equilibrio with the pressure of the amosphere; that is, if the mercury be depressed to M, that part of the weight of the atmosphere which corresponds with the quantity of mercury M B, will be sustained by the weight of the mercury, and the remainder M N will be sustained by the spring of the included air. The included air then, being pressed by a weight less than that of the whole atmosphere, becomes rarefied or expanded. By variously inclining the tube, or by immersing its lower end to greater depths in the bason, the included air may be made to bear more or less of the weight of the atmosphere, as may be gathered by measuring the perpendicular altitude of M above the surface of the quicksilver contained in the vessel C D, and subtracting it from the altitude B N, which corresponds with the weight of the whole atmosphere, and its contraction or dilatation observed: whence it appears that the density of air, though greatly rarefied, is proportional to the compressing force.

If two columns of uniform fluids, whose specific gravities differ, be equal in weight, and stand on equal bases, their heights will be reciprocally as their specific gravities (4, L, M. 6, T). The specific D

gravities of quickſilver and air are reſpectively 14019 and $1\frac{1}{4}$; therefore,

As the ſpecific gravity of
air, - - - - $1\frac{1}{4}$
Is to the ſpecific of mercury, - - - - 14019
So is the height of the column of mercury, - - 30 inches,
To the height of an equal column of air - - - 336456, or $5\frac{1}{4}$ Engliſh miles.

This would be the height of the atmoſphere, if it were uniformly of the ſame denſity; but as that is not the caſe, on account of the elaſticity which cauſes the upper parts to expand in proportion as the weight of the ſuperincumbent parts becomes leſs, the altitude muſt be much greater.

The denſity of the air in that part of the atmoſphere in which we live being ſhewn to be as the weight that compreſſes it, it is plain, if the conſtitution of the air in the ſuperior regions be of the ſame kind, that its denſity at any altitude will be as the weight or quantity of the ſuperincumbent air. Suppoſe A m (fig. 127) to be a column of the atmoſphere, and imagine the ſame to be continued at pleaſure beyond m, ſo as to reach its utmoſt limits. Let this column be divided into an indefinitely great number of equal parts, A b, b c, c d, &c. and the quantity of air contained in any one of thoſe parts, or its denſity, will be in proportion to the quantity of air which is ſuperincumbent on that

that part. Now, the difference between the quantities of air incumbent on any two contiguous parts is the quantity contained in the uppermoſt of thoſe parts: that is, for example, the quantity ſuperincumbent on d is leſs than that which is incumbent on c by the difference or part c d: therefore the quantities contained in the equal parts or diviſions are the differences between the incumbent maſſes of air taken in a regular ſucceſſion; and theſe quantities or differences have been ſhewn to be in proportion to the incumbent maſſes. * Now, it is demonſtrable, that if any ſucceſſion or ſeries of magnitudes do increaſe or decreaſe in ſuch a manner, that the differences ſhall be in proportion to the magnitudes themſelves, then thoſe magnitudes, and conſequently their differences, ſhall be in a continued geometrical progreſſion: whence it fol- G
lows, that the denſities or quantities of air contained in the equal diviſions or parts A b, b c, c d, &c. muſt decreaſe in a continued geometrical progreſſion.

On theſe conſiderations is founded the barome- H
trical method of meaſuring the elevations of mountains, or other eminences. The principles made uſe of may be explained as follows:

If a barometer were carried upwards with an I
uniform motion through the column of air A m,

* Let $a, b, c, d,$ &c. be magnitudes, whoſe differences are as the magnitudes themſelves.

| | |
|---|---|
| That is | $a-b : b :: b-c : c :: c-d : a$, &c. |
| Then | $ac = bb,\ bd = cc$, &c. |
| And | $a : b : c : d$, &c. |

 (fig.

(fig. 127) its elevation above the ſurface of the Earth would increaſe by the continual addition of the equal ſpaces A b, b c, c d, &c. ſo as to be ſucceſſively repreſented by the natural ſeries of the numbers 1, 2, 3, &c. but the mercury in the tube would continually deſcend ſo as to paſs through heights that would be proportional to the preſſures or denſities of the air (52, B, C) at A, b, c, d, &c.

K that is to ſay, while the elevations above the ſurface of the earth increaſe arithmetically the heights of the mercury in the tube will decreaſe in a continual geometrical ſeries (35, G).

L Now, it is well known, that if a continued geometrical ſeries, beginning with unity, be ranged in order, with an arithmetical ſeries, beginning with 0, or a cypher, the numbers of the latter ſeries will be the logarithms of the correſpondent numbers of the other. Such are the numbers before us; for the greateſt denſity of the air, or greateſt height of the mercury, may be called unity, and anſwers to an elevation of 0, or nothing above

M the Earth's ſurface. The elevations above the Earth's ſurface will therefore be the logarithms of the heights of the mercury in the barometer.

N If therefore we were provided with a table of logarithms, or an arithmetical ſeries of known unities or meaſures, adapted to that geometrical ſeries which expreſſes the gradual deſcent of the mercury, while it is carried with an uniform motion upwards, the differences of the logarithms of any two given heights of the mercury would in

fact

fact be the difference of the elevations above the Earth's surface, or it would be the perpendicular space through which the barometer had been carried, in order to produce that descent of the mercury.

But as there is no such table in being, it would become necessary to compute directly from the properties of the geometrical series, if there were not a method of applying the common tables of logarithms to this purpose. It is a property of all logarithms, that if the difference between the logarithms of two numbers be taken in one set of logarithms, and the difference between the logarithms of the same two numbers be taken in logarithms of another form, the proportion between these two differences will be constant for all pairs of numbers so taken *. From hence if the difference of two elevations be experimentally found, and the respective heights of the mercury observed at each, it will not be difficult to deduce any other difference of elevation from observations of the heights of the mercury at each.

* In the following series,

| | | | | | | |
|---|---|---|---|---|---|---|
| 0. | 3. | 6. | 9. | 12. | 15. | logar. |
| 0. | 2. | 4. | 6. | 8. | 10. | logar. |
| 1. | n. | $n^2$ | $n^3$ | $n^4$ | $n^5$ | numbers. |

it is obvious, that the logarithm of any number in one series has a constant ratio to the logarithm of the same number in the other series. And the differences between the logarithms of two given numbers in the two series of logarithms will have the same constant ratio, as being the logarithms of one and the same number, namely, the quotient of those two numbers.

P An example will render this clear. Suppose the height of the mercury in a barometer be 29.565 inches, and the height of the mercury in another barometer, placed at an elevation of 710 feet above the former be 28.770 inches, it is required to find the difference of elevation of two barometers, whose mercurial columns stand respectively at 28.9 inches, and 27.5 inches.

Q If the altitude of the mercurial column, 30 inches, be taken as unity, or the first term of the geometrical series, the two first altitudes will become fractions $\frac{29565}{30}$, and $\frac{28770}{30}$ of that unity, the number 710 being the difference of the logarithms, or correspondent terms of the arithmetical series of elevation, taken in feet. Take now the difference of the common logarithms of those fractions, or, which is the same, the difference of the logarithms of their numerators, thus:

| | | |
|---|---|---|
| 29.565 its logarithm, | - - | 1.4707779 |
| 28.770 its logarithm, | - - | 1.4589399 |
| | Difference, | .0118390 |

R And this difference .0118380 will bear the same proportion to the difference of elevation 710, as the difference of the common logarithms of any other two altitudes of the mercury will be to the difference of elevation between them (37, 0): so that with respect to the thing required,

| | | |
|---|---|---|
| From the logarithm of 28.9 | - | 1.4608978 |
| Take the logarithm of 27.5 | - | 1.4393327 |
| The difference is | | .0215651 |

And as .0118380 : 710 : : .0215651 : 1294 feet.

As

As the two firſt terms are of conſtant uſe in s
theſe computations, it will be advantageous to reduce them to the ſimpleſt expreſſion: thus, as .0118380 : 710 :: 1 : 60000 nearly; ſo that, inſtead of working the proportion with the two firſt terms, it will be ſufficient to multiply the difference of the logarithms by 60000, and the product will give the elevation in feet of one barometer above the other.

But to multiply this difference by 60000 is the T
ſame as to multiply it by 10000, and by 6. The multiplication by 10000 is effected by moving the decimal point four places farther to the right: whence it is ſeen, that the decimal point being removed four places to the right, converts the difference of the logarithms into a number that requires to be multiplied by 6 to reduce it into feet. The number itſelf is therefore the height in U
fathoms and decimal parts:

Conſequently, the ſhorteſt general rule for V
meaſuring heights by the barometer is, take the difference of the logarithms of the heights of the mercury at both ſtations, and the four firſt figures following the decimal point will be the fathoms, and the reſt a fraction of a fathom, expreſſing the elevation.

It is evident, however, that this rule ſuppoſes W
the ſpecific gravity of the mercury to remain unaltered, becauſe its height could not otherwiſe be a ſettled meaſure of the denſities of the air that ſuſtains it. It is likewiſe implied, that the denſity of

the air is subject to no other change than may arise from its diminished compression in ascending towards the upper regions of the air: but neither of these positions can be admitted in the actual practice.

x For all bodies expand and occupy larger spaces when their temperature is increased. The mercury in the barometer, when heated, will be specifically lighter, and will consequently ascend from that cause, even though the pressure of the air should remain unchanged: and the air, when expanded by the same agent, will not diminish its pressure after the usual ratio in ascending: or, if the same geometrical series be supposed to be retained, the unity of its logarithms will be greater than before, and the general rule, (39, v) instead of giving fathoms, will give a number of some larger measure. Thus, we see, that the rule can be true only with respect to air of a given temperature, and that in all other cases it will require to be corrected.

Y By a very valuable set of experiments it is found, that the mercury in a barometer changes its altitude by heat, according to the following table:

Z If the mercury in the baromer stand at 30 inches when the temperature is 32°; its changes will be for every degree,

| | between 0 and 32° | between 32° and 52′ | between 62 and 72 | between 72 and 92 |
|---|---|---|---|---|
| | falls 0.0034 inch. | ris. 0.0033 | ris. 0.0032 | ris. 0.0031 |

A In order therefore that we may know the effect of the air's pressure on the barometer, it is required, that

that its height ſhould be corrected by the addition or ſubtraction of theſe quantities, according to the number of degrees of temperature above or below 32°, and in proportion to its height.

It is alſo pretty well eſtabliſhed from barometri- B
cal obſervations, and from experiments made with air of various denſities, that its expanſions by heat are as in the following table. The height of the mercury is taken to be the mean between the heights at the extremities of the column of air, and the column entitled correction ſhews the expanſion or diminution of the column of air in thouſandth parts C
of the elevation given by the general rule (39, v).

Mean height of BAROMETER 30 inches.

| Mean Temperature of the air. | | Correction. | Difference for 1 inch barom. |
|---|---|---|---|
| 92° | Add to Logarithmic elevation. | 156.381 | 6.0925 |
| 82 | | 131.188 | 5.111 |
| 72 | | 105.047 | 4.0925 |
| 62 | | 78.427 | 3.0555 |
| 52 | | 51.335 | 2.0000 |
| 42 | | 25.193 | 0.9816 |
| 32 | | 0. | 0. |
| 22 | Subtract | 24.242 | 0.4722 |
| 12 | | 47.532 | 0.9259 |

The philoſopher who undertakes to meaſure D
heights barometrically ſhould be provided with two portable barometers, of the beſt conſtruction, on which he may read off the height of the mercurial columns to the 500th part of an inch; each barometer

be the true elevation, if the mean between the temperatures indicated by the detached thermometer be 32°.

H Thirdly. But if the mean temperature of the column of air, as indicated by the detached thermometers, be above or below 32°; find the mean between the two altitudes of the mercury: extract from the table (41, c) the two numbers in the column of differences that range oppoſite the two temperatures, between which the mean temperature of the column of air lies; multiply each by the number of inches (and parts, if the elevation be great) which the mean altitude of the mercury differs from 30 inches. Subtract theſe products from the reſpective oppoſite numbers in the column of corrections, if the mean altitude of the mercury be leſs than 30 inches, but add, if it be greater. Find the difference between theſe two remainders or ſums, and multiply it by the number of degrees by which the mean temperature exceeds the lower of the two adjacent temperatures in the table. Divide this product by 10, and add the quotient to the leaſt of the two remainders or ſums laſt mentioned. The ſum will be the true correction in thouſandth parts of the logarithmic elevation. Reduce it into fathoms, by multiplying it into the logarithmic elevation, and dividing by 1000. This quotient being added to the logarithmic elevation, if the mean temperature exceed 32°, or ſubtracted, if it fall ſhort of 32°, will give the true elevation or perpendicular diſtance between the two barometers.

Example. Suppose the following observations I
to be made, it is required to find the elevation, or vertical distance between the barometers.

| Lower station. | Upper station. |
|---|---|
| Caernarvon quay. | Peak of Snowdon. |
| Height of Mercury, 29.976 in. | 26.289 inches. |
| Attached thermometer, $62\frac{1}{2}°$ | - $46\frac{1}{2}°$ |
| Detached thermometer, 62 - | 46 |

The computation. By the table (40, z) the K
reduction for the lower barometer comes out 0.1, which, subtracted from 29.976, gives 29.876. By the same table, the reduction for $46\frac{1}{2}°$, with a column of 26 inches, comes out .042, which, subtracted from 26.282, leaves 26.240 inches. Now, the logarithms of the reduced altitudes, 29.876, and 26.240, are 1.4753225, and 1.4189638, the difference of which is .0563587, or (43, G) 563.587 fathoms.

The mean temperature between 62° and 46° is L
54°, and consequently the logarithmic result will require corrections by the second table. The mean between the two barometrical heights is 28 inches, or 2 inches below 30. The two numbers in the column of difference opposite the temperatures 52° and 62° are 2.0000, and 3.0555; these, multiplied by the number of inches, or 2, give 4.0000 and 6.111; the number 4.0000, subtracted from its opposite in the column of correction, 51.335, leaves 47.335; and the number 6.111, subtracted from 78.427, leaves 72.316; the difference between these

these remainders 47.335 and 72.316 is 24.981, which, multiplied by 2, the number of degrees by which the mean temperature 54° exceeds 52°, the lower of the two adjacent temperatures in the table, gives 49.962. This product, divided by 10, is 4.9962; which quotient added to 47.335, the least of the two remainders, makes 52.331, the true correction in thousandth parts of the logarithmic elevation.

M The true correction 52.331, being multiplied by the logarithmic altitude 563, produces 29462.353: this divided by 1000 affords a quotient of 29.462353: which is the true correction in fathoms, to be added to the logarithmic elevation, because the mean temperature exceeds 32°: the sum, namely, 563.587, added to 29.462353, makes 593.049353 fathoms, or 3558.297118 feet, for the true elevation required*.

N The intelligent reader will readily perceive, that though the decimals in this computation are mostly retained, yet, it will in general be sufficiently exact, and much less operose, if only the two first decimal figures of any number be retained.

O The advantages of this method, compared with the geometrical method of measuring elevations, are,

* This method, which is taken from Col. Roy's excellent paper in the 67th volume of the Philosophical Transactions, may be rendered more easy in the practice, by extending the tables so as to give the corrections at sight, as in some measure done in the original; but the brevity of the present work prevented their being copied here.

first,

first, the instruments are neither very expensive nor even difficult for an ingenious philosopher to make in any country where he can procure quicksilver and glass tubes; but the geometrical method demands instruments of considerable price, which can scarcely at all be constructed by the most ingenious person who is destitute of the tools, and unacquainted with the artifices required to render them correct. Secondly, The barometers require no other adjustment than to observe previously, whether they agree, and to allow for their difference. The barometrical observations are likewise easily made; whereas, on the contrary, the previous adjustment and subsequent use of instruments for measuring angles require a degree of precision and skill not usually obtained without practice. Thirdly, The error of observation in the barometrical method for all elevations is nearly a constant quantity, never amounting to so much as half a fathom for a mistake of the 500th of an inch; but any error either in the measurement of lines or angles proportionally affects the result; so that the greater the elevation required to be measured, the larger the quantity of error. Fourthly, The barometrical observations require no particular circumstances of advantage, either in the figure or situation of the mountains required to be measured, nothing more being required than that both stations be accessible. These observations, and the computation, are performed after the same method in all cases; but in the geometrical method, if the horizontal distance

of

of the two stations be considerable, or if there be not a convenient plain for measuring a fundamental base, the operation becomes very complicated, and the chance of error is multiplied.

It must not, however, be disguised, that the principles of the geometrical method are established and sure, and that an extreme degree of exactness may be obtained in this way by good instruments in the hands of a skilful observer. Whereas the modifications of the atmosphere, with respect to the effect which exhalations of various kinds, and the greater or less abundance of the electric matter, may have in expanding the air, without changing its temperature, are not yet sufficiently known to render the corrections altogether as perfect as might be wished. Future observations must point out these, and in the mean time it is to be remembered, that the elevations determined by the barometer, when the extreme temperatures of the column of air do not greatly differ, and when the air is cold and dry, are most to be depended on *.

* For a more full account of this curious subject, consult De Luc's Recherches sur les Modifications de l'Atmosphere... Sir George Shuckburgh's valuable Observations made in Savoy, in order to ascertain the height of mountains by means of the barometer, inserted in the Philosophical Transactions, vol. 67, with Col. Roy's, and Mr. de Luc's papers, in the same volume: also Damen's Dissertatio Physica et Mathematica de Montium Altitudine barometro metienda; and the authors by him cited.

CHAP.

# CHAP. II.

## OF THE REFRACTIVE POWER OF THE AIR; AND THE CAUSE OF TWILIGHT.

THAT the celeſtial ſpace or heavens is either Q
nearly or abſolutely vacuous, appears from the ſmall reſiſtance the planetary bodies ſuffer in their motions; ſuch reſiſtance, if it obtain at all, being too minute to be clearly aſcertained by any obſervations we are in poſſeſſion of. Light therefore, when incident on our atmoſphere, paſſes from a rarer to a denſer medium, and ought, according to the principles of optics, to be refracted towards the perpendicular (I. 262, A). And this is accordingly the caſe. Let the circle A B C (fig. 130) R
repreſent a ſection of the Earth, and the external concentric circle the ſurface of the atmoſphere; let H N be the ſenſible horizon of a place A, and S the Sun beneath the horizon; then a ray of light incident on the ſurface of the atmoſphere at I, will, inſtead of proceeding to a, be refracted towards the perpendicular I E, and that continually the more as the denſity of the medium becomes greater, ſo that it will arrive at A after paſſing through the curve I A; and a ſpectator at A will behold the Sun in the line of the laſt direction of the ray, namely, in that of A S, the tangent to the curve. The apparent ele- S
vation which a celeſtial body ſuffers when its rays

fall with the greatest obliquity, to wit, when it is seen in the horizon, is about thirty-three minutes of a degree: at other altitudes the differences between the true and apparent places are less, the incidences and refractions being less considerable.

T Hence it comes to pass, that we see the celestial bodies for some time after they are set, and before they rise in reality, by which means we enjoy about three days in the year more day-light than otherwise we should: but in the northern parts, where the sun rises and sets more obliquely, and the atmosphere being condensed by cold, refracts more strongly, the difference is much greater.

U The refraction, as well as all the other phenomena produced by the atmosphere, are variable, as the density of the air changes. This variation renders the observation of low altitudes uncertain, as the allowance for refraction cannot be collected with great precision from any tables. The trigonometrical admeasurement of the heights of lofty mountains is likewise rendered less accurate from this cause.

V A method of discovering the height of the atmosphere is deduced from observations of the morning and evening twilight. Notwithstanding the very great transparency of the air, it may be rendered visible by means of the rays of light reflected from its parts in all directions. This effect is seen when the beams of the Sun are admitted into a room through the window-shutter, and may frequently be observed when the Sun shines through the chasms

chasms or openings in a dark cloud: from which cause it happens, that those bodies which emit a very small quantity of light are not to be discerned in this stronger light. In the day-time the stars w are invisible, and the flame of a candle can scarcely be seen in the sun-shine: were it not for this illumination the sky would appear black, and the shady sides of objects would be of a dark colour, nearly the same as at midnight.

The sun shining on the globe of the earth can x illuminate but one hemisphere at once, as has already been shewn; but it is not so with the atmosphere which environs the globe. Thus, the illuminated part of the globe terminates at D and d, (fig. 128) but the atmosphere is enlightened as far as B and b. In consequence of this it happens, that those parts which have already entered into the dark hemisphere, and to which therefore the Sun is set, must still enjoy a degree of light that continues as long as any of the enlightened part of the atmosphere remains in view. This light, which Y gradually decays after sun-set, or increases before sun-rise, is called the twilight. Let A H C D d b (fig. 129) represent a section of the Earth in the plane of the Sun's azimuth, and let the space contained between the concentric circles represent the atmosphere: then, the Sun's rays in the directions S B, s b, will illuminate half the globe D c d, and the atmosphere will be enlightened as far as B and b on each side within the dark hemisphere; which enlightened part, so long as it continues above the

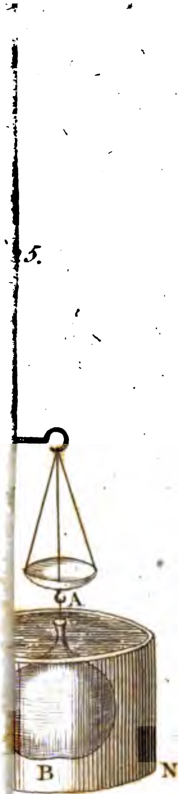
horizon of any place, will cause a twilight at that place. The ray SDB is a tangent to the Earth at D, and meets the circumference of the atmosphere at B. From B draw the line Bh, a tangent to the Earth at A, which continue towards N; hN will then represent the horizon, in which the extreme point B of the enlightened part of the atmosphere will be situated; that is, twilight will be just beginning or ending at the place A. The angle SBN, which is equal to the angle AED, will be the angle of the Sun's depression beneath the horizon HN; and the angle AEB is the half of AED. Hence, if the depression of the Sun beneath the horizon, and the semidiameter of the Earth be known, it will be easy to find the height of the atmosphere. For, in the right angled triangle ABE,

| | | | |
|---|---|---|---|
| As the sine complement of half the Sun's depression | - - | AED | 8° 30′ |
| Is to the Earth's semidiameter | - | AE | 3437 miles, |
| So is radius | - - | sine | 90° |
| To the hypothenuse | - - - - | EB | 3475 miles. |

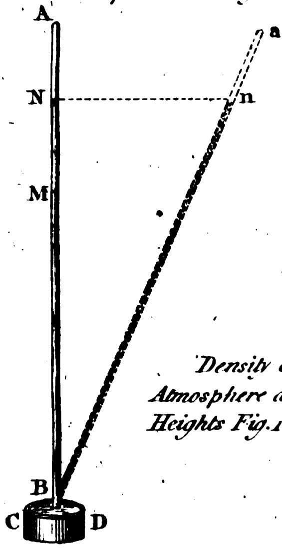
The difference between which and the semidiameter of the Earth, is the line HB, or height of the atmosphere, 38 geographical, or 44 English miles. The angle of the Sun's depression is known by the time elapsed between the beginning or end of twilight, and the rising or setting of the Sun; and it is judged to be twilight so long as the illumination of the atmosphere prevents the smaller fixed stars from appearing. It is also observed, that the evening are always longer than the morning twilights,

which

5.

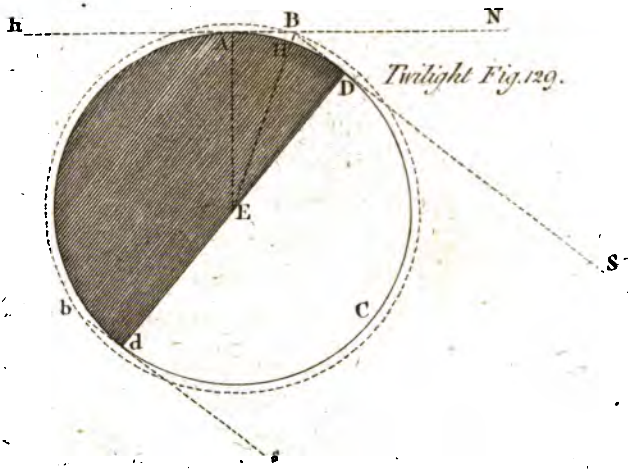



Torricellian Experiment Fig 126.




Density of the Atmosphere at different Heights Fig.127.


Twilight Fig.129.



which muſt ariſe from the rarefaction of the air over the place, after the day's ſun-ſhine. A ſimilar difference is obſerved between the twilights of ſummer and winter.

This explanation is ſufficient to ſhew the cauſe B of the twilight. But in ſtrict computation the refraction to which the light is ſubject three times before it comes to the eye ſhould be allowed for, and will ſomewhat diminiſh the height deduced.

## CHAP. III.

### CONCERNING THE CAUSES BY WHICH THE SPRING OF THE AIR IS ALTERED AND WINDS ARE PRODUCED.

THE expanſion of air by heat, while the preſſure C remains the ſame, has already been taken notice of (40, X). Heat therefore increaſes its ſpring, as may be ſhewn by the following experiment:

Let A D B (fig. 131) repreſent a hollow-glaſs- D ball, having a narrow bent tube A C G B affixed to it. The lower part of the bent tube, and part of the ball, is filled with mercury, as in the figure; the ſurface A B within the ball being on the ſame horizontal line with the ſurface at C in the tube. The parts of the mercury will be then in equilibrio, the external ſurface C being preſſed by the weight

of the atmoſphere, and the internal ſurface AB being preſſed by the ſpring of the included air, which is equal to that weight. But if the ball be immerſed in boiling water, the increaſed ſpring of the included air preſſing on the ſurface AB, will raiſe the mercury from C to G, and there ſuſtain it, namely, at the height of $8\frac{4}{7}$ inches, when the mercury in the Torricellian tube ſtands at 30 inches. And as the contained air is not ſenſibly dilated by the extruſion of ſo ſmall a quantity of mercury, the ſuſtentation may be regarded as the entire effect of its ſpring. The ſpring of the included air at the heat of boiling water is therefore not only equal to the weight of the atmoſphere, but likewiſe to an additional preſſure of more than $\frac{8}{30}$ of that weight.

E By the ſame inſtrument, it is found, that the elaſticity of the air is weakened by immerſion in very cold or freezing mixtures. And concluſions ſimilar to theſe may be made by various methods, which the attentive learner will readily diſcover.

F In the foregoing experiment the air was prevented from expanding, in conſequence of its increaſed ſpring, by the preſſure of the mercury; but if, inſtead of putting mercury into the ball, a ſmall quantity be made to hang in the tube, as at GH, it will by its motion indicate the dilatation or contraction of the included air.

G By a method ſimilar to this it is found, that from the point 0 in Fahrenheit's thermometer to the heat of boiling water, or 212°, common dry air expands ſo as to occupy an additional ſpace more than before, equal to the fraction

tion .48421 of its former bulk. But the expanſions of moiſt air are much greater*.

It will not be difficult from theſe experiments to point out the cauſes of many phenomena that happen in the air. For, if any part of the air be either heated, or charged with vapor, it will expand, and in conſequence of that expanſion become ſpecifically lighter than before. It muſt, therefore, by the laws of hydroſtatics, aſcend, and the circumambient air muſt preſs in on all ſides to ſupply its place. Hence the cauſe of the aſcent of ſmoke in a chimney. The air which paſſes through the fire, or comes within a certain diſtance from it, is rarefied, and aſcends, giving place to the cold air that preſſes in: this in its turn becomes rarefied, and the aſcending current of air continues as long as the fire is kept up, the wind drawing from all parts towards the chimney.

If the fire were in the open air, the heated air would ſtill aſcend in a current, and the cooler air preſs in on all ſides; that is to ſay, a wind would be generated, which would conſtantly blow towards the fire. The quantity of air rarefied by any fire we can make is ſo ſmall, that the wind produced by that means is too inconſiderable to be perceived at any great diſtance from the fire; but the rarefactions

* Muſchenbroek's Cours de Phyſique may be conſulted for an abſtract of what has been done reſpecting the expanſion of air by *Amontons*, and others. But the moſt copious and valuable ſet of experiments are thoſe of Col. Roy, in the Philoſophical Tranſactions, part 2, for the year 1777.

arising from natural causes are sufficient to produce all the winds that agitate the atmosphere.

K The sensible horizon is not only divided into 360 degrees, like other great circles, but also into 32 equal parts, called points of the compass, which are again subdivided into halves and quarters. The points of the compass have each a separate name. The points of intersection between the meridian and the horizon are termed North and South: and two other points, at the distance of 90° from the North and South, are termed East and West: these four are denominated cardinal points. The intermediate points take their names from the cardinal points between which they are situated, as in the figure, where the initial letters N. S. E. W. (fig. 132) stand for the words North, South, East, West.

L A wind is named from the point of the compass from which it blows.

M The different winds may, with respect to their direction, be reduced into three classes, viz. general, periodical, and variable winds.

N General winds blow always nearly in the same direction. In the open seas, that is, in the Atlantic and Pacific Oceans, under the equator, the wind is found to blow almost constantly from the eastward; this wind prevails on both sides of the equator to the latitude of 28°. To the northward of the equator, the wind is between the North and East, and the more northerly the nearer the northern limit; to the southward of the equator, the

wind

wind is between the South and Eaſt, and the more ſoutherly the nearer the ſouthern limit.

Between the parallels of 28° and 40° ſouth lat. O
in that tract which extends from 30° Weſt to 100° Eaſt longitude from the meridian of London, the wind is variable, but by far the greater part between the N. W. and S. W. ſo that the outward bound Eaſt India ſhips generally run down their eaſting on the parallel of 36° ſouth.

Beyond the northern limit of the general wind in P
the Atlantic Ocean, the weſterly winds prevail, but not with any certainty of continuance.

Near the weſtern coaſt of Africa, within the Q
limits of the general wind, the winds are found to be deflected towards the ſhore to ſuch a degree, that they are found to blow from the N. W. and S. W. quarters for the moſt part, inſtead of the N. E. and S. E. as is the caſe farther out at ſea.

The general winds are uſually called trade-winds. R

In the Atlantic Ocean, the S. E. trade-wind ex- S
tends as far as 3° north, and the N. E. trade-wind ceaſes at the 5th degree N. In the intermediate ſpace are found calms, with rain, and irregular uncertain ſqualls, attended with thunder and lightning. But this ſpace is ſhifted farther to the northward or ſouthward, accordingly as the Sun's declination is more northerly or ſoutherly.

Periodical winds are thoſe which blow in a cer- T
tain direction for a time, and at ſtated ſeaſons change and blow for an equal ſpace of time from the oppoſite point of the compaſs. Theſe may be divided

divided into two claſſes, viz. monſoons, or winds that change annually; and land and ſea-breezes, or winds that change diurnally.

u While the Sun is to the northward of the equinoctial, that is to ſay, in the months of April, May, June, July, Auguſt, and September, the wind blows from the ſouthward over the whole extent of the Indian Ocean; namely, between the parallels of 28° N. and 28° S. latitude, and be-between the eaſtern coaſt of Africa and the meridian which paſſes through the weſtern part of Japan. In the ſea between Madagaſcar and New Holland, the S. E. wind prevails as far as the equator, where it is deflected, and blows into the Arabian Gulf and Bay of Bengal from the S.W. Between Madagaſcar and the main land of Africa, a S.S.W. wind obtains, and coincides with the S. W. winds in the Arabian Gulf. To the northward of New Holland, the S. E. wind is predominant, but varies very much among the iſlands: and between the peninſula of Malaca and the iſland of Japan, a S. S. W. wind prevails. All this is to underſtood for the aforementioned months.

v But in the other months, October, November, December, January, February, and March, a remarkable alteration takes place. In the ſea between Madagaſcar and New Holland, the S. E. wind extends no farther to the northward than about the 10th degree of ſouth latitude, the other 10 degrees being occupied by a wind from the oppoſite point of the compaſs, or N. W. at the ſame time that the winds

winds in all the northern parts of the Indian Ocean ſhift round, and blow directly contrary to the courſe they held in the former ſix months. Theſe winds are called monſoons, or ſhifting trade-winds.

Theſe changes are not ſuddenly made. Some w
days before and after the change there are calms, variable winds, and dreadful ſtorms, attended with thunder, lightning, and rain.

On the greater part of the coaſts of lands ſituated x
between the tropics, the wind blows towards the ſhore in the day-time, and towards the ſea in the night. Theſe periodical winds are termed the land and ſea breezes, and are much affected, both in their direction and return by the courſes of rivers, tides, &c.

Variable winds are thoſe which are ſubjected to y
no period, either in duration or return, and are too well known to need deſcription.

If the air were uniformly of the ſame denſity at z
the ſame height, and the lighter parts always repoſed upon the heavier, it is evident that, the lateral preſſure being equal in every horizontal direction, it would remain at reſt. But if, on the contrary, any portion or part of the air were heavier than the reſt, it would deſcend, or if lighter, aſcend, till the equilibrium was reſtored; ſo that either the diſplaced air would occaſion a wind, diverging from a central ſpace in conſequence of the deſcent or pouring down of the heavier air, or elſe the air ruſhing in, would occaſion a wind converging to a central ſpace to ſupply the lighter aſcending ſtream. It A
is

is therefore evident, that any agent that alters the denſity of a part of the air will produce a wind.

B The denſity of air is changed by compreſſion, and by heat. Its elaſticity is increaſed by the addition of moiſture, and electricity may have likewiſe ſome effect of the ſame kind. The compreſſion the air ſuffers in the natural courſe of events, is nearly uniform, and experiments are wanting to decide, whether the addition of moiſture to air at any of the uſual temperatures does not augment its denſity as much as the increaſed elaſticity diminiſhes it; neither have any methods been yet deviſed to ſhew, whether air in different ſituations with reſpect to electricity is altered in its dimenſions. In conſidering the cauſes of winds, the principal agent to be attended to muſt therefore be heat.

C If the Earth did not revolve on its axis, it is plain that the Sun, being ſtationary over one particular ſpot, would rarefy the air at that ſpot: it would conſequently aſcend by the preſſure of the circumambient, and leſs rarefied air, till it arrived at a region in which the air was ſufficiently rare to ſuffer it to expand on all ſides: and thus there would be produced a converging wind near the ſurface of the Earth, and a contrary or divergent wind in the upper region of the air. But ſince the Earth does revolve on its axis, and the Sun therefore is not ſtationary, it muſt follow, that the place where the air is moſt rarefied will be found ſucceſſively in every point of the parallel over which the

Sun

Sun moves in the courſe of a day. And as this place continually moves to the weſtward, the lower air muſt as conſtantly follow it. Hence we have the origio of the general N. E. and S. E. trade-winds, which no doubt would extend over the whole of the ſpace between the tropics, were it not for the different temperatures of the continents and iſlands over which the Sun paſſes. For the ſurface of earth is more heated than that of the ſea, by reaſon that the tranſparency of the water permits many of the rays of light to paſs to its interior parts before they are ſtifled and loſt. The air therefore, contiguous to the land, being more heated than that which reſts upon the ſea, will prevent the regularity of the effect. Thus, near the weſtern coaſts of Africa and America, the winds blow from the weſtward, to ſupply the conſtant rarefaction thoſe heated lands produce.

The general N. E. and S. E. trade-winds, pro- D
ducing in the upper region of the air winds in the contrary directions, ſeem to be the cauſe of the weſterly winds which are obſerved to prevail between the latitudes of 28° and 40°.

In accounting for the monſoons, or periodical E
trade-winds, it is neceſſary to mark the peculiar circumſtances which obtain in the Indian Ocean, and which are not found in the Atlantic or Pacific Oceans. They ſeem to be theſe. That the ocean is bounded to the northward by ſhores, whoſe latitude does not exceed the limits of the general trade-wind, and that the general trade-wind falls on lee-ſhores to the weſtward.

The Sun being twice in the year vertical in the equator, and never departing more than $23\frac{1}{2}°$ from thence, causes the air in that climate to be hotter that at any other place on the ocean; and is the occasion of the trade-wind, as has already been shewn. Such a rarefied space must extend across the Indian Ocean, and produce a S. E. wind to the southward, and a N. E. wind to the northward of the equator, over which, in the upper regions of the air, the winds return in the contrary directions. This we accordingly see happens in the months of October, November, December, January, February, and March. But when the Sun declines to the northward, and heats the land there, the air contiguous to those lands become rarefied, and the lower air has a tendency to move that way. This tendency increases as the Sun advances farther North, so that the whole body of the lower air to the northward of the equator moves towards the northern lands, notwithstanding the equatorial rarefaction, which must be supplied by the upper or returning current. It seems then that the body of the lower air in the northern part of the Indian Ocean is determined as to its course by the greater rarefaction: if the rarefaction at the surface of the land be greater than that at the equator, the wind blows to the North, and the contrary happens when the equatorial rarefaction is greatest. When the northerly trade-wind prevails, it blows out of the Arabian Gulf upon the coasts of Arabia, Aynan, and Zanguebar, and is reflected into the straits of

Mofambique. And at the other feafon, the general foutherly wind feems to be reflected to the weftward by the fame caufe.

Thefe, or fome fuch like, are probably the caufes H
of the winds that prevail in the Indian feas. But the obfervations we are in poffeffion of are too few and too inaccurate for the purpofe of forming a theory.

On the fame principles it will not be difficult I
to account for the land and fea-breezes. For, becaufe the land is heated in the day-time, the wind muft blow in fhore to fupply the place of the afcending rarefied air: and in the night the land cools, and condenfes the air, occafioning the land breeze.

The circumftances that produce the variable K
winds are referable to thofe already noticed, but act fo differently in particular cafes and fituations, that it is fcarcely practicable to reduce them to any rule.

When feveral winds converge fwiftly to one L
point, the air afcends with great rapidity, and acquires a whirling motion, like that of water defcending in a funnel. And as the centrifugal force in this whirling motion of the water is often fufficient to counterpoife the lateral preffure, and to prevent its approaching the central part, it frequently happens, that a perforation is feen quite through the body of the fluid. In like manner, the centrifugal force of the air may become equal to the preffure of the atmofphere, and confequently leave a void fpace about the center of the motion. This phenomenon

is

is called a whirlwind, and sometimes produces fatal effects. For, partly by the expansion of the air included in houses or other buildings, and partly by the violence of the ascending current, it happens, that bodies near the center of the whirl are blown up into the vacuum, or carried aloft with great impetuosity in a spiral motion.

If one of these whirlwinds happen at sea, the pressure of the atmosphere being taken off that part of the surface over which the vacuum is formed, the water, on the principle of the Torricellian tube, will rise to the height of thirty-two or thirty-three feet before it will be in equilibrio with the external pressure. The ascending warm air being most probably charged with vapours, will suffer them to be condensed as it arrives in a colder region, and thus the course of the current will be marked by the dense and opake vapor, and by the continual ascent a cloud will be formed above. These are the phenomena of water-spouts. At first a violent circular motion of the sea is observed for the space sometimes of twenty feet diameter; the sea rises afterwards by degrees into a tapering column of about thirty feet in height, at the same time that a cloud appears, from which a dark line or column descends. This column is met by another, which ascends somewhat like smoke in a chimney, from the lower or solid part of the spout. After this junction the cloud continually increases till the whirl ceases, and the appearance terminates

CHAP.

## CHAP. IV.

### OF SOUND; AND OF MUSIC.

When obtuse bodies move in elastic fluids, they N condense that part towards which they move at the same time that the part they recede from is rarefied. This condensation or rarefaction must produce an undulatory or vibrating motion in the fluid. Thus, if a body by percussion or otherwise be put into a tremulous motion, every vibration of the body will excite a wave in the air, which will proceed in all directions so as to form a hollow sphere; and the quicker the vibrations of the body succeed each other, the less will be the distance between each successive wave. The sensation ex- O cited in the mind by means of these waves which enter the ear, and produce a like motion in a thin membrane, stretched obliquely across the auditory passage, is called sound. But the term is frequently used to imply not only the sensation excited in the mind, but likewise the affection of the air, or of the sonorous body by which that sensation is produced. Thus, we say, that a sound is in the air, or that a body sounds when struck, though the affection of the air or body is very different from the sensation.

That bodies move or tremble when they produce P sound, requires no particular proof: it is evident in drums, bells, and other instruments, whose vibra-

tions being large and ſtrong, are therefore more perceptible: and it is equally clear, that a ſimilar vibration is excited in the air, becauſe this vibration is communicated through the air to other bodies that are adapted to vibrate in the ſame manner: thus, bells, glaſſes, baſons, and muſical ſtrings, will ſound merely by the action propagated from other ſounding bodies.

Q It is eſtabliſhed as well by mathematical reaſoning from the nature of an elaſtic fluid, whoſe compreſſion is as the weight, as from experiment, that all ſounds whatever arrive at the ear in equal times

R from ſounding bodies equally diſtant. This common velocity is 1142 Engliſh feet in a ſecond of time. The knowledge of the velocity of ſound is of uſe for determining diſtances of ſhips, or other objects: for inſtance, ſuppoſe a ſhip fires a gun, the ſound of which is heard 5 ſeconds after the flaſh is ſeen; then, 1142 multiplied by 5, gives the diſtance 5710 feet, or 1 Engliſh mile and 430 feet.

S When the aerial waves meet with an obſtacle which is hard, and of a regular ſurface, they are reflected; and conſequently, an ear placed in the courſe of theſe reflected waves will perceive a ſound ſimilar to the original ſound, but which will ſeem to proceed from a body ſituated in like poſition and diſtance behind the plane of reflection as the real ſounding body is before it. This reflected ſound is called an echo.

T The waves of ſound being thus reflexible, nearly the ſame in effect as the rays of light, may be

deflected

deflected or magnified by much the same contrivances as are used in optics. From this property of reflection it happens, that sounds uttered in one focus of an elliptical cavity are heard much magnified in the other focus; instances of which are found in several domes and vaults, particularly the whispering gallery at St. Paul's Cathedral in London, where a whisper uttered at one side of the dome is reflected to the other, and may be very distinctly heard. On this principle also is constructed the speaking trumpet, which either is or ought to be a hollow parabolic conoid, having a perforation at the vertex, to which the mouth is to be applied in speaking, or the ear in hearing.

In addition to the advantages we enjoy from the perception of sound, when the sense of seeing cannot be employed, and in conveying our thoughts to each other by means of the associations formed between words and ideas, we receive great pleasure from the combination of sound known by the name of music.

If a body be struck, and the vibrations excited be all performed in equal times, the undulations produced in the air will be so likewise, and a simple and uniformly similar sound will be produced, except as to loudness or intensity; for, as the vibrations grow less strong, the sound decays. But if the vibrations excited be various and dissimilar, a like variety of dissimilar undulations will be produced in the air; and the sound must be harsh, as if several

sounds were heard together. The first of these sounds is a musical tone, and the latter a noise.

w This is confirmed by experience; for we find that those bodies which are the most uniform in their texture, and by consequence best adapted to vibrate simply and isochronally, always produce the most musical tones; as for example, masses of elastic metal, brass, cast-iron, and the like. And this tone is more strictly musical if the metal be so formed as to vibrate in the simplest manner possible. Thus, a hollow metallic vessel or bell, if it be well formed and not damaged in the tuning, will give but one uniform musical tone, or at least the tones produced will consist of one predominant or principal tone, and several others that have a perfect musical agreement with it. A wire of an uniform thickness, stretched over two hard bridges or fulcrums, will produce the same effect. Musical tones may be obtained by various means; but it will sufficiently answer our present purpose to attend only to the simplest method wherein strings or wires are made use of.

x Experience and reason have established the following positions respecting the vibrations of chords or strings.

y The forces or weights which are necessary to draw an extended chord AB (fig. 133) out of its place to the distances ce, cf, cg, are directly proportional to those distances, provided the chord be not too much drawn aside.

There-

Therefore, ſince the forces with which the chord Z
returns to its firſt ſituation, when ſet at liberty, are always in proportion to the ſpace it has to paſs through, the vibrations muſt all be performed in equal times.

If chords differ only in thickneſs, the times of A
their vibrations will be directly as their diameters.

If chords differ only in tenſion, the times of B
their vibrations will be inverſely as the ſquare roots of the weights by which they are ſtretched.

If chords differ only in length, the times of their C
vibrations will be directly as their lengths.

That tone produced by a ſtring that vibrates D
quickly is termed acute or ſharp, when compared with the tone of a ſtring that vibrates ſlower: and the tone produced by the latter is called grave or flat, when compared with that of the former.

If two chords be ſtruck, either at the ſame inſtant E
or in intermediate ſucceſſion, the coincidence of ſound is pleaſing or diſpleaſing, accordingly as the two tones produced ſtand related to each other in gravity or acuteneſs: if they be ſo related as to afford pleaſure, the coincidence is called a concord, but if not, it is termed a diſcord.

A ſet of tones which follow each other, and afford F
pleaſure, is called melody; a ſet of cotemporary tones which afford pleaſure, is called harmony.

The more frequently the vibrations of two chords G
coincide with each other the perfecter the concord will be; thus, two equal ſtrings, equally ſtretched, will each give the ſame tone; the vibrations of the one

will coincide with those of the other, and the concord will be most perfect: again, two strings, differing only in length, the one being half the length of the other, will vibrate the one twice while the other vibrates once, the coincidence will be at every second vibration of the shorter string, and a concord will be produced, but less perfect; if the strings be in length as 2 to 3, the coincidence will be less frequent, namely, at the third vibration of the shorter string, and the concord will be still less perfect: and so forth.

H By the help of these principles all stringed instruments are constructed; that series of musical tones being selected, which experience has shewn to be best adapted for the purposes of melody and

I harmony. The series is called the diatonic scale, and its properties, together with the names of the tones, may be seen in the following scheme:

| Names. | Lengths. | Perfection. |
|---|---|---|
| Unison, or fundamental | 1 : 1 | Most perfect concord. |
| Second - - | 10 : 9 | Discord. |
| Third greater | 5 : 4 | Imperfect concord. |
| Fourth - - - | 4 : 3 | Imperfect concord. |
| Fifth - - - - | 3 : 2 | Perfect concord. |
| Sixth greater - - | 5 : 3 | Imperfect concord. |
| Seventh greater - | 15 : 8 | Discord. |
| Octave - - - - | 2 : 1 | Perfect concord. |

K The above is called the sharp series, in contradistinction to the flat series, or scale, wherein the third, sixth, and seventh are less or flat, being in

the ratios of 6 : 5, 8 : 5, and 9 : 5. There are likewiſe other intermediate tones uſed in practice, as the ſecond leſs, and fourth greater, whoſe lengths are as 16 : 15, and 7 : 5. All theſe are found in the conſtruction of inſtruments: that by their means the performer may place his fundamental, or principal note, on any of the tones at pleaſure, and uſe the other tones which ſtand in the above relations to it; ſuch being found ſufficiently near for practice, though not ſo perfectly accurate as in the ſeries the inſtrument is formed for.

The notation of muſic, and the relations of different ſcales to each other, together with the other particulars on which the rules for compoſition and accompaniment depend, require too copious an explanation to be admitted in this place.

## CHAP. V.

### A DESCRIPTION OF VARIOUS INSTRUMENTS, CONSISTING CHIEFLY OF SUCH AS DEPEND ON THE PROPERTIES OF THE AIR FOR THEIR EFFECTS.

M THE mercury in the Torricellian tube ſtands at the height of about thirty inches, by means of the preſſure of the air; and in conſidering the phenomena of winds, we have ſeen that this preſſure is not every where alike, nor always the ſame at any particular place. In conſequence of this it happens, that the mercury in the Torricellian tube does not preſerve the ſame invariable altitude; for, when the air at any place is denſe, the mercury ſtands at a greater height than when it becomes lighter (32, B): thus the tube becomes an inſtrument to indicate the varying weight of the atmoſphere, and when fixed in a proper frame with graduations to meaſure the altitude of the mercury, is known by the name of the barometer. The variations are between the altitudes of $27\frac{1}{2}$ and $30\frac{1}{2}$ inches.

N The heights of two barometers cannot be compared together with any exactneſs, unleſs they be both conſtructed in the beſt manner. The ſpecific gravity of the included mercury ought to be accurately found; and it is neceſſary to boil it in the tube, for the purpoſe of effectually excluding the air and moiſture from within. If the ſurface of the mercury

mercury exposed to the air be larger than that in the tube, and this last be less than half an inch in diameter, the mercury will not rise to its full height. This difference ought to be known, and allowed for between different barometers.

The instrument, (fig. 131,) is used under the O
name of the marine barometer, it being useful at sea, where the common barometer is of little service, on account of the ship's motion, which causes the mercury to librate up and down in the tube. But as this barometer is subject to alteration, on account of heat and cold, as well as on account of change in the weight of the air; and the distinguishing the effects of each is attended with some little trouble, it is not much in use on shore.

There are many contrivances for enlarging the P
divisions on the barometer, such as inclining the tube, and the like; but they are all subject to inconveniences, on account of friction, which the upright barometer is free from.

An instrument similar to the marine barometer Q
was formerly made use of to indicate the varying temperature of the weather. For the marine barometer is also a thermometer, and its variations being thus occasioned by two causes, prevent its being applied to either purpose. The thermometer, or instrument used to exhibit degrees of heat and cold, is therefore constructed by the use of other fluids.

The property of expansion by heat not being R
peculiar to air, but common to all bodies, we are at

liberty

liberty to choose any substance in nature for a thermometer. In this choice it is required, that the body made use of should be such, that its expansions may be the effect of heat alone, that they may be easily and correctly measured, and that the body may be capable of performing its office in temperatures very distant from each other. As the pressure of the atmosphere is not considerable enough to alter the dimensions of dense bodies in any sensible degree, it is plain that their mutations will indicate the effects of heat alone, and consequently they must be very proper for the matter of thermometers: but these mutations being very small in proportion to the whole bulk, solid bodies must be inconvenient for the purpose, on account of the great length required to make them perceptible: but in fluids, by means of proper vessels, it will be easy to render the least alteration visible; for if the neck or stem of any glass-vessel be very small in proportion to the contents of the bulb or bottle, the least expansion of the included liquor will occasion a visible rise in the neck. Thus, A B (fig. 134) represents a glass tube, whose end A is blown into a ball: this ball, and part of the tube, being filled with quicksilver, the least change of the bulk of the quicksilver, and consequently of the temperature of the circumambient air, or contiguous bodies, is shewn by a rise or fall of the surface in the tube; the quantity of which is indicated by the scale a b, affixed to the frame of the instrument.

Quick-

Quickfilver is the beft fluid for thermometers, because it is not fubject either to alter its expanfibility, or to foil the tube, and gives befides a very extenfive fcale of divifions. The thermometer ufed in Britain is graduated according to the fcale of the celebrated Fahrenheit. There are 180 divifions or degrees between the freezing and boiling water points; the freezing point being reckoned 32° above 0, or the commencement of the fcale*. The degrees are counted both upwards and downwards from 0. A good thermometer muft poffefs the following properties. The upper end muft be hermetically fealed, and the empty fpace above the quickfilver muft contain no air, or at moft very little. This circumftance is afcertained by holding the inftrument with the ball uppermoft; in which fituation the mercury will immediately run fo as to fill the whole capacity of the tube. The fcale muft be well adjufted, and divided according to the capacity of the tube. To prove this, let the thermometer be taken from its fcale, and laid in fnow, or pounded ice, juft beginning to melt: it fhould be covered nearly as high as the freezing point, or 32°, is fuppofed to lie. When the mercury becomes ftationary, mark the tube with the edge of a knife where it ftands, or, if there be a mark ready made, as there commonly is, obferve whether it accurately

* Reaumur's fcale, principally ufed by the French, begins at the freezing point, and proceeds both ways from 0. From freezing to boiling water is 80 degrees.

agrees

agrees with the furface of the mercury, if it does, the freezing point is well fettled. Wrap now feveral folds of linen rags or flannel round the tube of the thermometer nearly as high as the fuppofed boiling point; hold the ball of the thermometer in the afcending current of boiling rain-water about two or three inches below the furface; pour boiling water on the rags three or four times, waiting a few feconds between each time, and wait fome feconds after the laft time of pouring on water before the boiling point is marked on the tube, in order that the water may recover its full ftrength of boiling, which is confiderably checked by pouring on the boiling water. This laft experiment muft be made when the barometer ftands at 29.8 inches. The adjuftment of the fixed points being thus afcertained, fasten the thermometer again to its fcale, and agitate it fo as to break or divide the thread of mercury in the tube. By varioufly inclining the inftrument the feparated portion of mercury may be made to reft in different parts of the tube, and its length obferved on the fcale. If its length in every part of the tube correfponds to the fame number of degrees, the fcale is well divided. This laft object is by no means to be neglected: for it feldom happens that the diameters of thermometer-tubes are fufficiently regular to admit of a fcale divided into equal parts. Such a fcale will ufually produce an error of upwards of a degree near the temperature of 120°, though the

the fixed points be ever ſo well ſettled; and in ſome inſtances the error may even amount to four or five degrees.

Thermometers with ſmall bulbs, and tubes in proportion, are the moſt uſeful. For a large volume of mercury requires a conſiderable time to be either heated or cooled, and if it be immerſed in any liquid, it will change the temperature of the liquid much more than a ſmaller inſtrument would have done, and conſequently is leſs adapted to ſhew the temperature of the liquid at the time of its immerſion. If the ſcale of a thermometer be of a dark colour, and the thread of mercury ſmall, its ſtation will be rendered more diſcernible by ſlipping a piece of white paper behind the tube. u

The preſſure of the atmoſphere on the outſide of a thermometer not being counteracted by the ſpring of any included air, is exerted in diminiſhing the ſize of the bulb, and ſuſtains the mercury ſomewhat higher than it would ſtand, merely by reaſon of its temperature. This is proved by breaking off the ſealed end of the tube; in conſequence of which the mercury immediately falls. This quantity varies with the weight of the atmoſphere, but the quantity of the variation can ſeldom amount to more than the tenth part of a degree. Thermometers with ſpherical bulbs are leſs acted on by the weight of the atmoſphere than others. v

If the bent tube C E D (fig. 135) be filled with water, and the ſhorter leg E C immerſed in the water contained in the veſſel A B, the water will w

all

all flow out at the aperture D, and the vessel will be emptied. For the pressure that supports the water in the leg C E is equal to the weight of the atmosphere, and is counteracted by the weight of the column E C, and the pressure that supports the water in the leg D E is the same weight, but counteracted by the column E D. And as E D is longer than E C, the pressure of the atmosphere on D will be less effectual than that on C; consequently the whole mass of water in the tube will move towards the orifice D, receding from the greater pressure. This instrument is called a syphon, and is sometimes used to draw liquors out of casks that are so placed as not conveniently to be moved.

x A very probable account of the cause of intermitting springs may be given on the principle of the syphon. For, let G F C (fig. 136) represent a cavity or receptacle in the bowels of a mountain, from the bottom of which C, proceeds the irregular cavity or syphon C E D: then, if by springs or otherwise the receptacle begin to fill, the water will at the same time rise in the leg C E of the syphon till it has attained the horizontal level H H: when it will begin to flow out by means of the leg E D, and will continue to increase in the quantity discharged, as the water rises still higher, till at length the syphon will emit a full stream, and by that means empty the receptacle. At this period the stream will cease, till the receptacle being again filled, will again exhibit the same appearance. And these periodical returns of flood and cessation will

be

be regular, if the filling of the reservoir be so; but the interval of the returns must depend on the dimensions of the apparatus, and the quantity of water furnished by the springs.

The action of that very useful instrument the Y common pump, depends on the pressure of the atmosphere. It consists of a pipe C D (fig. 137) whose lower end C is immersed in water: at B is fixed a valve opening upwards, and in the superior part of the tube is worked a piston A, fitted very closely in the pipe by means of leather. In this also is a valve opening upwards. Now, if the part above B be filled with water, to render the whole air-tight, the piston A being thrust down to B, and afterwards raised, will leave a vacuum or void space between B and A, into which the air contained in the lower part of the pipe C B, will expand itself. The spring of this air being thus weakened by the expansion, will no longer counterpoise the effect of the pressure of the atmosphere, and the water will rise in the tube till the equilibrium is restored. By depressing the piston A, the valve B is suffered to close, and a part of the air between the valve and piston escapes through A. After a few strokes the whole of the included air is extracted, the water rises through the valve B, and is discharged by the piston A. This operation may be continued at pleasure. But if Z the height B C be more than 34 feet, the water will not rise to the valve; for a column of fresh water of that length being equal to the weight of the atmosphere, it can be raised no higher by that

weight.

weight. Thus it happens for the same reason that the mercury in the barometer never rises beyond a certain height; and if a pump, finished with the utmost exactness on the principle here described, be made to work in mercury, it will not raise it beyond that height.

A The fire-engine acts by means of the weight and elasticity of the air. For it is composed of two barrels, E and D, (fig. 138) in each of which a solid piston or plunger is worked by means of a double lever. These barrels communicate with the water by a pipe, not expressed in the figure: they also communicate with the strong cylinder or vessel CC, by the pipes L and T. At M and K in the barrels are valves opening upwards, and at L and T are valves which open towards the cylinder. In the figure, the piston in D being raised, the water rushes in at K, while that in E being depressed, forces its contents into the cylinder through the valve T. At the next stroke the barrel E raises the water, while the contents of the barrel D are forced into the cylinder: and thus the alternate actions of raising and forcing may be continued at pleasure. Now, the water being forced into the cylinder, compresses the air contained within into a small space; and this air reacting on the water, drives it in a continual stream through the pipe P O Q R, which may be directed as necessity shall require.

B The great force of compressed air is shewn by many experiments, particularly in the performance

of

of the wind-gun. Fig. 139, represents a section of this instrument. A K is the barrel, containing a ball at K. This barrel is contained within another larger tube C D R E, and in the intermediate cavity the air is compressed and kept. M N is a cylindrical cavity in the stock or butt end of the piece, in which a piston works, for the purpose of forcing the air into the before-mentioned cavity. The air is prevented from returning by the shut or valve P, which is opened by the air, as it is forced in, but, at other times, is kept shut by the spring of the included air. At L is placed another valve, pressed close by means of a spring on the orifice of the barrel, to prevent the air from escaping. A wire passing through a hole, rendered air-tight by wet and greasy leather, is affixed to this valve, and appears afterwards at O, in the form of a trigger. When the trigger is drawn back, the valve L opens, and the air rushing out, drives the ball with a force that seems not much less than if it were discharged from a musquet.

A variety of curious and pleasing fountains may be formed by the help of the properties of the air combined with hydrostatical principles. The following is one of the simplest. A B C D (fig. 140) is a copper vessel, near two thirds filled with water: at M is screwed in the tube I G, the junction being made air-tight by means of wet and greasy leather, and in the upper part of the tube is fixed a stop-cock H. The stop-cock being opened, a forcing syringe is screwed on at I, and a great quantity of

air injected, whence the air in the cavity A B F E being very much condensed, presses on the surface of the included water. The stop-cock being then shut, the syringe is removed, and an adjutage screwed on in its place; through which, if the stop-cock be again opened, the water will spout forth with great violence.

D Fig. 141, is a drawing of a very ingenious fountain, whose construction will be better understood from the section exhibited in fig. 142. B C is an open dish, or vessel. R S and T U are reservoirs for water; each of which is divided into two by the partitions V I and X Y. The tube E F passes through without communicating with the upper reservoir, and serves to convey water from the bason B C to the part T X Y of the lower reservoir. The tube G H forms a communication between the part T X Y of the lower, and R V I of the upper reservoir. The tube I K forms a communication between the part R V I of the upper, and Y X U of the lower reservoir. And the tube M L forms a communication between the part Y X U of the lower, and I V S of the upper reservoir. Lastly, there are openings at O N P Q, to fill or evacuate the reservoirs, and an adjutage pipe D I communicating with the part I V S. The mode of action is this: water being poured into the upper reservoir by the openings O and N, the fountain is set upright, the openings being previously closed, and also the adjutage D. The bason B C must then have water poured into it, till it ceases to run down the pipe E F. In this state the

fountain may be said to be charged. For the water that has passed down E F condenses the air in the part T X Y, and also in the superior part R V I, by means of the tube of communication O N. In the same manner the water passes from the upper reservoir down the tube I K into the other lower part Y X Q, and condenses the air there as well as in the other upper part V I S, by means of the pipe of communication M L. The water in the upper part V I S is therefore pressed by air condensed by the weight of the column I K, and also of the column E F, because I K is in effect pressed by this last. Open the adjutage D, and the water will issue out and rise (20, R) to nearly the height of both the columns E F and I K together. The water in both those columns must descend, but as the tube E F is supplied by the falling jet that issues out of the chamber V I S, while the tube I K is supplied by the water from the chamber R V I, the fountain will continue to play till the upper chambers V I S and R V I have respectively emptied themselves into the lower chambers T X Y and Y X Q.

In many mechanical engines, where the force E
of an elastic fluid is required, the steam of boiling water is made use of, because it is easily obtained, is prodigiously elastic, and may be quickly deprived of its elasticity.

The first engine we have any account of, for F
raising water by the force of steam, was constructed about a century ago upon the principle of the figure, (fig. 143) where H represents a copper boiler

boiler placed on a furnace. E is a strong iron vessel communicating with the boiler by means of a pipe at top, and with the main pipe (A B) by means of a pipe at bottom. A B is the main pipe immersed in the water at B. D and C are two fixed valves, both opening upwards, one being placed above, and the other below, the pipe of communication. Lastly, at G is a cock that serves occasionally to wet and cool the vessel E, by water from the main pipe, and F is a cock in the pipe of communication between the vessel E and the boiler.

The engine is set to work, by filling the copper in part with water, and also the upper part of the main pipe above the valve C, the fire in the furnace being lighted at the same time. When the water boils strongly, the cock F is opened, the steam rushes into the vessel E, and expels the air from thence through the valve C. The vessel E thus filled, and violently heated by the steam, is suddenly cooled by the water which falls on it upon turning the cock G, the cock F being at the same time shut, to prevent any fresh accession of steam from the boiler. In consequence of this, the steam in E becoming condensed, leaves the cavity within almost intirely vacuous: the pressure of the atmosphere at B, therefore, forces the water through the valve D till the vessel E is nearly filled. The condensing cock G is then shut, and the steam cock F again opened; the steam rushing into E, expels the water through the valve C, as it before

did

N°.22.Vol.II.face p.84.

f the Air

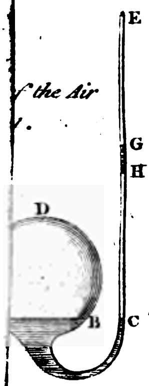
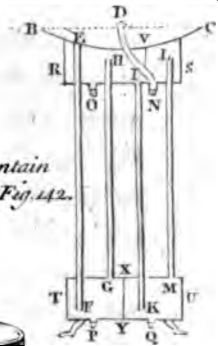


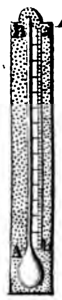

Fig.136.

Fountain Fig. 141.

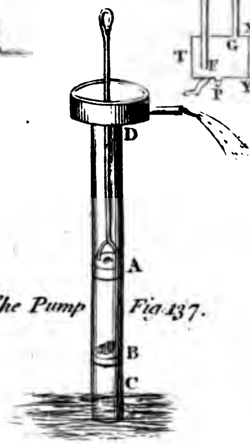

Fountain Fig.142.




Thermometer Fig.134.




The Pump Fig.137.



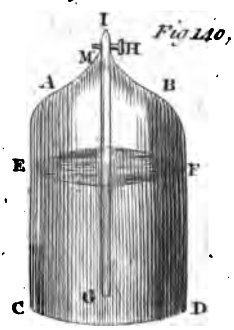


Wind Gun Fig.139.



Fountain by condensed Air

Fig.140,



did the air. Thus E becomes again filled with hot ſteam, which is again cooled and condenſed by the water from G, the ſupply of ſteam being cut off by ſhutting F, as in the former operation: the water conſequently ruſhes through D, by the preſſure of the atmoſphere at B, and E is again filled. This water is forced up the main pipe through C, by opening F and ſhutting G, as before. It is eaſy to conceive, that by this alternate opening and ſhutting the cocks, water will be continually raiſed, as long as the boiler continues to ſupply the ſteam.

For the ſake of perſpicuity, the drawing is di- H
veſted of the apparatus that ſerves to turn the two cocks at once, and of the contrivances for filling the copper to the proper quantity. The engines of this conſtruction were uſually made to work with two receivers or ſteam veſſels, one to receive the ſteam, while the other was raiſing water by the condenſation. This inſtrument has been ſince improved, by admitting the end of the condenſing pipe G into the veſſel E, by which means the ſteam is more ſuddenly and effectually condenſed than by water on the outſide of the veſſel.

The advantages of this engine are, that it may I
be erected in almoſt any ſituation, requires but little room, and is ſubject to very little friction in its parts: its diſadvantages are, that great part of the ſteam is condenſed, and loſes its force upon coming into contact with the water in the veſſel E, and that the heat, and elaſticity of the ſteam muſt

be increased in proportion to the height the water is required to be raised to. On both these accounts a large fire is required, and the copper must be very strong, when the height is considerable, otherwise there is danger of its bursting. The following engine is much to be preferred when the work to be done is heavy, and is less chargeable in fuel, because it acts by means of steam whose density is not much greater than that of the common air.

K In fig. 144, H represents the copper boiler on its furnace. E is a cylindrical vessel of iron, in which the piston O O moves up and down; the edges of the piston being armed with oakum and grease, render the whole cavity between the piston and the bottom of the cylinder air-tight. F is a cock to admit steam into the cylinder from the boiler. I K is a lever, attached to the piston at I, and at K to the piston of a pump which works on that side. P Q is a solid piston moving in the pipe R M, and loaded with a heavy weight at P. A B C is the main pipe that receives the water forced from R M through a valve C opening outwards. N is an air-vessel communicating with the main pipe. D is a valve opening upwards, and at M is the water to be raised.

L In the drawing, the engine is represented in the position it has at the end of a forcing stroke, which is likewise its position when at rest. Suppose the main pipe A B C to be filled with water, and the water in the copper H to boil strongly.

The

The cock F being then opened, the ſteam ruſhes into the cylinder, and being much lighter than the air, riſes to the top, and expels the air through a valve in the bottom of the cylinder. This being accompliſhed, F is ſhut, and the cock G communicating with the main pipe is opened, which immediately condenſes the ſteam, by violently ſpouting cold water againſt the bottom of the piſton. A vacuum being thus obtained, the preſſure of the atmoſphere forces the piſton down to the bottom of the cylinder; the lever I K is moved of courſe, the piſton P Q with its weight is raiſed, and the water aſcends in the pipe M R upon the principle of the common pump. The cock G being now ſhut, and F opened, the ſteam enters the cylinder, and counteracts the preſſure of the atmoſphere on the piſton O O. In conſequence of this, the weight P prevails, and drives down the piſton R Q, forcing the water through the valve C into the main pipe and its air veſſel. The uſe of the air veſſel is to prevent the main pipe from burſting by the ſudden entrance of the water; for the air at N being elaſtic, gives way to the ſtroke, and its reaction during the time of elevating the piſton P Q continues the motion of the water, ſo that its velocity is no more than half what it would have been if it had been impelled by ſtarts, and reſted during the raiſing of the piſton. By opening the cock G and ſhutting F, the ſteam is again condenſed, the preſſure of the atmoſphere again prevails, and thus the work may be continued at pleaſure.

M In this drawing likewiſe, the mechaniſm is omitted, that ſerves to open and ſhut the cocks. This office is performed by a beam and ropes attached to the lever IK, ſo that the attendance required is very little more than is neceſſary to ſupply the boiler with water, and to prevent the fire from going out.

N The chief advantage of this engine beyond the former is, that the water may be forced to any height without increaſing the force of the ſteam, which never need be much greater than that of the atmoſphere; and therefore the boiler is very little endangered. The maximum of its power depends upon the area of the piſton OO; for the larger the area, the greater the column of the atmoſphere that preſſes it, and conſequently the heavier the weight P or counterpoiſe may be. If OO the piſton be 36 inches in diameter, it will be preſſed by a column of the atmoſphere equal in weight to a column of mercury of that diameter, and 30 inches in height; that is to ſay, almoſt 7 ton.

O But, notwithſtanding the great ſkill and contrivance diſplayed in this engine, it is at preſent almoſt entirely ſuperſeded by one of a much better conſtruction, invented and perfected by Meſſrs. Watt and Boulton, of Birmingham. In their engine, inſtead of the piſton OO being depreſſed by means of the weight of the atmoſphere, the ſteam is thrown upon it, the upper part of the cylinder E being cloſed, and the rod L of the piſton, which is ſmooth and poliſhed, being admitted through a perforation, which

which is wadded ſo as to be air-tight. The aſcent of the piſton is obtained by letting the ſteam out of the cylinder into a veſſel at a conſiderable diſtance, where it meets with, and is condenſed by a jet of cold water; while a vacuum is conſtantly maintained in the lower part of the cylinder by the action of the pump that carries off the injection water. The force of ſteam employed in this engine is uſually equal to one atmoſphere and a quarter, and the whole apparatus is regularly worked by the principal lever I K. The advantages of this conſtruction are, that by increaſing the force of the ſteam the power of the engine may be increaſed, without enlarging the diameter of the cylinder; and a leſs expence of ſteam is required on account of the condenſation being performed at a diſtance from the cylinder, which is not therefore cooled by the injection of the cold water. This laſt circumſtance renders the engine capable of making a greater number of ſtrokes in a minute with a much leſs expence of fuel than the old engine. In ſome of the lateſt improved engines the action of the ſteam is rendered equal on the lever, by adapting the figure of the arch at its extremity, ſo that the lever is in effect rendered longer, towards the end of the ſtroke, where the power of the ſtream is weaker.

The elaſticity of the air affords a method of determining the depth of the ſea in places where a line cannot be uſed. Fig. 145, is a machine for this purpoſe. A repreſents a large ball of fir

or

or other light wood, varnished over, to preserve it from the effects of the water; B is a hollow glass vessel, whose contents in sea water are exactly known; suppose, for instance, two pounds: its neck C terminates in a small orifice, and is bent downwards, to prevent the escape of the included air, when it is immersed in water. At E is a spring-hook, which, if at liberty, would stand in the position e, but is pressed through a slit in the stem at the bottom, and kept to its place by hooking on the weight D. The whole instrument thus prepared is suffered to sink in the water. And the consequence is, that as it sinks, the pressure of the water continually increasing, forces its way into the vessel, and condenses the air contained within; but when it arrives at the bottom, the weight D striking first, is stopped, while the rest of the apparatus proceeds a little onwards, by reason of its acquired velocity. The hook E being thus disengaged from the weight, flies back, and leaves it intirely, so that the ball A is at liberty to rise again to the surface. From the quantity of water contained in B at its emergence, it is easy to determine the depth it has descended to. For, since the density of air is as the compressing weight, the bulk of the same quantity of air, under different pressures, must be inversely as the weight. And experiment shews, that the mean weight of the atmosphere is equal to about 32 feet of sea-water: therefore, at the depth of 32 feet, the air included in the vessel C will sustain the pressure of

two

two atmospheres, and consequently will be condensed into half its former space; at 64 feet depth it will sustain the pressure of three atmospheres, and be condensed into one third of its first space, and so forth. Suppose, for example, an empty ball, as above described, capable of holding two pounds troy of sea-water, were to descend to an unknown depth in the sea, and at its return was found to contain 1lb. 11 oz. 18 dwts. of water, it is required to find the depth? Then, As the bulk the air was compressed into, when at the bottom of the sea, which is expressed by 2 dwts. Is to the bulk of the air before immersion, expressed by 2 lb. So is the weight of the atmosphere, by which the air was compressed before immersion, which is expressed by 32 feet of water, To the weight by which the air was compressed when at the bottom of the sea, 3840 feet. From which deduct 32 feet for the pressure of the atmosphere, and the remainder, 3808 feet, indicates the depth of the sea.

This method is subject to two objections. The first is, that probably the specific gravity of the sea may be different at different depths, and consequently the pressures may not be as the depths: the other is, that air in very great condensations does not strictly follow the ratio of the pressure, but resists in a greater degree. A careful series of experiments may however indicate the allowances necessary to be made on both accounts, and in small depths the instrument is sufficiently accurate

on

on the principle already laid down. If this instrument were to be applied to measure considerable depths, the temperature of the submarine regions would require to be found and allowed for.

R It is a well-known fact, that an empty vessel, that is to say, a vessel containing air, immersed in water with the mouth downwards, will not become filled, because the spring of the air will prevent the water from entering, as may be easily seen by the help of a wine-glass. The diving-bell is constructed on this principle. It consists of a large vessel, or kind of cask, so loaded with lead as to sink when empty, with the mouth downwards. In the top is fixed a cock to let out the air, and a strong pane of glass to afford light to the divers, who sit on a circular bench in the inside. This machine is lowered into the water about twelve feet at a time, and at each pause air is sent down in smaller bells to the divers, and by them received into the cavity of the great bell, for the purpose of expelling the water that enters as the pressure condenses the included air. After it has arrived at the bottom of the sea, the operators continue by the same means to replenish the air which becomes foul by breathing, suffering the impure air to escape by the cock in the upper part, as they receive fresh air by the barrels or small bells; so that by this contrivance they can remain under water as long as they please.

S The air-balloon is of two kinds; the one intended to contain heated air, and the other in-

flammable air or hydrogen. Hot air occupies more ſpace when colder (54, G), and hydrogen is much lighter at a given temperature than the common air of the atmoſphere. From this it follows, that any maſs of either heated or inflammable air, at liberty, will aſcend in the atmoſphere with a force of buoyancy equal to the difference between its own weight and the weight of an equal bulk of common air (9, B). If the heated air or the hydrogen be included in a bag, and the weight of the bag be leſs than the difference juſt mentioned, the bag will be carried upwards, though with a leſs degree of force, namely, with a force equal to the difference leſſened by the weight of the bag. This is commonly called an air-balloon; which, though its figure is not eſſential to its property of aſcending, we will ſuppoſe to be a globe. If the magnitude of a balloon be increaſed, its power of aſcenſion, or the difference between the weight of the included air and an equal bulk of common air, will be augmented in the ſame proportion; that is to ſay, in proportion to the cube of its diameter. But the weight of the covering or bag will not be increaſed in ſo great a proportion. For its thickneſs being ſuppoſed the ſame, it is as the ſurface it covers, or only as the ſquare of the diameter. This circumſtance is the cauſe why balloons cannot be made to aſcend, if under a given magnitude, with cloth or materials of the ſame thickneſs.

Fig.

u Fig. 146 represents the balloon first invented. It consists of an immense bag of canvas, or other cloth, painted with a composition that may lessen its susceptibility to take fire. A net covers the upper part of its surface, from which proceed ropes that sustain a gallery to carry the adventurers and fuel. The lower part is affixed to the gallery, and open to receive the streams of heated and rarefied air, produced by means of fire maintained in an iron grate, suspended in the middle of the orifice. The first inflation of the balloon is effected by means of a fire made in a proper apparatus on the ground, and the attached grate serves only to maintain the requisite degree of rarefaction, by furnishing a supply of heated air in the room of that which is gradually condensed by cooling. It is ascertained from experiment, that the rarity of the air in these machines depends solely on its heat and its property of cooling slowly; and it is likewise established with a considerable degree of certainty, that the weight of the included air is at a medium, about two thirds of the weight of an equal bulk of the air of the atmosphere. This balloon is raised or lowered while in the atmosphere, by increasing or diminishing the fire.

v Small balloons of thin paper, raised on this principle by the flame of a sponge, or ball of cotton dipped in spirits of wine, have been exhibited in every part of Europe.

w The hydrogen gas balloon, fig. 147, is preferable to the other, in the present early state of our

our knowledge. It is usually formed of thin silk varnished over. When filled with hydrogen its tube of communication A is usually closed, so that the air is prevented from escaping. The adventurers are placed in a car or small vessel B, attached to the balloon by strings, proceeding from a net that covers its upper part. They carry bags of sand with them to serve as ballast, and the end of the tube of communication, as well as a string that by pulling may open a valve in the top of the balloon, are continued down into the car. By those means they have, for a limited time, the power of ascending or descending at pleasure. For the power of ascension is increased by emptying one or more sand-bags, or diminished by suffering the hydrogen gas to escape either by the tube or through the valve. It may be observed, that the hydrogen gas, on account of its greater lightness, will not descend through the tube of communication, unless, either by its own expansion from heat, or by the diminished pressure of the atmosphere at great heights, it is made to escape while the balloon is fully inflated; but it will issue from the upper valve, when open, in all circumstances whatever.

The hydrogen gas produced in the large way, by the effusion of diluted sulphuric acid on iron shavings or turnings, is rather less than one fifth of the weight of an equal bulk of atmospherical air. It is estimated that a cubic inch of iron gives a cubic foot of hydrogen gas, and the strong

sulphuric

sulphuric acid, sold in London, requires to be diluted by five times its bulk of water, for this experiment.

Y To give at pleasure a progressive motion to air-balloons, in any required direction, is a problem of great importance in this newly discovered art of penetrating into the superior regions of the atmosphere. Many wild and absurd schemes for this purpose have been offered to the consideration of the public; and some that have been carried into effect have served only to evince the ignorance or the artful quackery of their projectors. Little however of real value has been yet done towards accomplishing this purpose. The grand difficulty of the attempt consists in the large surface of resistance exposed to the surrounding fluid, which has hitherto been such, that the quantity of air required to be displaced is so great, that the strength of the voyagers cannot displace it with any considerable velocity; that is to say, when they have given a small degree of velocity to the machine, the resistance of the air becomes such, that their whole strength will be employed in over-
Z coming it, instead of adding to the velocity. The principal object therefore must be, to construct the balloon of such a figure as that it may move through the air without displacing any considerable quantity of it. As to the application of the strength, it may be done by a variety of methods. It is required that it should be exerted on the air in the opposite direction to that intended to be produced

in

in the balloon, and as no mechanism can bestow or create strength (1. 73, E) the simplest machine will be the best, because the loss by friction will then be least.

The uses to which machines of this kind may be applied are numerous, and will easily occur to any ingenious person. It will probably be long before the experiment will be performed in a sufficiently cheap way to admit of its being applied to the ordinary purposes of travellers. Its use on extraordinary occasions, for the conveyance of intelligence in military operations; for penetrating into places inaccessible by other means; or, for making philosophical observations on the superior regions of the atmosphere, are sufficiently obvious. We cannot, however, boast of any addition having been made to the stock of atmospherical knowledge, though very many aerial voyages have been performed. The probable causes of this are, that the balloons have seldom ascended above two miles high; that the novelty and grandeur of the scene beheld from a balloon has prevented a strict attention to the phenomena that may have presented themselves; and more especially, that most of the experiments were performed by ignorant and mercenary imitators, who have been much more desirous of taking the advantage of the surprize and credulity of the vulgar, than of making valuable observations, or relating them with fidelity.

The invention of the heated air balloon is the undoubted right of the brothers, Messrs. Stephen

and John Mongolfier, who made the first experiment at Avignon in November 1782. The first balloon raised in the atmosphere by means of inflammable air was constructed by public subscription, opened by M. Faujas St. Fond at Paris. Messrs. Roberts were appointed to construct the machine, and M. Charles to superintend the work. It was launched from the Champ de Mars August 27, 1783. The first human being that ascended into the air by means of an air-balloon was M. Pilatre de Rozier. He was afterwards accompanied by M. Gironde de Vilette, and afterwards by the Marquis d'Arlandes. The balloon used in these experiments rose by heated air, and was constructed by John Mongolfier at Paris. It was prevented from escaping by ropes. The first aerial voyage was performed with the same balloon by M. Pilatre de Rozier and the Marquis d'Arlandes, who passed over the city of Paris November 21, 1783. The first aerial voyage with a balloon filled with inflammable air was made by Messrs. Charles and Robert from Paris December 1, 1783. They were carried about twenty-seven miles in one hour and three quarters. The great rarity of inflammable air was first ascertained (in 1766) by Mr. Cavendish, and the idea of its application to the purpose of floating a bag in the atmosphere was explained by Dr. Black in his lectures next following that period. Several philosophers made attempts to carry this into effect previous to June 1782, and succeeded so far as to inflate soap-bubbles with inflam-

inflammable air, which rapidly aſcended to the ceiling of the room. But it is to the philoſophic ſpirit and liberality of our neighbours the French that we are indebted for this experiment being completely performed in the large way, without whoſe encouragement it might probably have long remained nothing more than a happy thought*.

On the 14th of June, 1785, the intrepid and ingenious Pilatre de Rozier fell a victim to the new art in which he was the firſt adventurer. He attempted to croſs the Britiſh channel in company with a gentleman, whoſe name was Romain. His balloon conſiſted of two parts: the upper contained inflammable air, and the lower part was a balloon for heated air. By this ingenious addition it was expected, that a power of aſcending or deſcending at pleaſure, without loſs either of ballaſt or of inflammable air, would have been obtained. When the unfortunate travellers were at the eſtimate height of about ſix thouſand toiſes, the upper balloon took fire near the top, and burſt. The apparatus immediately fell to the ground. Pilatre de Rozier firſt came to the earth: no ſigns of life were perceived in him, but his companion is ſaid to have uttered an exclamation before he expired.

This much lamented event is ſuppoſed to have ariſen either from the electricity of the clouds ſetting fire to the ſtream of inflammable air that

* For a further account of this ſubject, the Engliſh reader may have recourſe to Cavallo's Hiſtory and Practice of Aeroſtation.

issued from the upper valve, or from the inflammable air that escaped, forming a train of communication between the upper balloon and the fire beneath, which in its ascent was continually brought into the place before occupied by the balloon. This last opinion is rendered most probable, from the agitation and apparent distress observed in the travellers a short time before the catastrophe. They had prudently lowered the stove before Pilatre de Rozier opened the upper valve. The efflux of inflammable air occasioned by this last manœuvre was probably the immediate cause of their destruction *.

## CHAP. VI.

### OF THE AIR-PUMP AND ITS USES.

THE air-pump is one of the most useful of all philosophical instruments, whose actions depend on the properties of the air. By the help of this machine, all that has been shewn concerning the weight and elasticity of the air, is demonstrated in the most simple and elegant manner. Its construction is as follows: E F G H (fig. 148) is a square table of wood, A A are too strong barrels or tubes of brass, firmly retained in their position by the piece T T, which is pressed on them by screws O O, fixed on the tops of the brass pillars N N. These barrels communicate with a cavity in the lower part

* See the Courier de l'Europe for July 1, 1785.

D. At the bottom within each barrel is fixed a valve, opening upwards, and in each a piston works, having a valve likewise opening upwards. The pistons are moved by a cog-wheel in the piece T T, turned by the handle B, and whose teeth catch in the racks of the pistons C C. P Q R is a circular brass-plate, having near its center the orifice K of a concealed pipe, that communicates with the cavity; in the piece D at V is a screw that closes the orifice of another pipe, for the purpose of admitting the external air when required. L M is a glass-receiver, out of which the air is to be exhausted. It is placed on the plate P Q R, first covered with a wet sheep-skin, or smeared with wax, to prevent the air from insinuating under the edge of the glass.

When the handle B is turned, one of the pistons C is raised, and the other depressed; a void space is consequently left between the raised piston and the lower valve in the correspondent barrel: the air contained in the receiver L M, communicating with the barrel by the orifice K, immediately raises the lower valve by its spring, and expands into the void space; and thus a part of the air in the receiver is extracted. The handle then being turned the contrary way, raises the other piston, and performs the same act in its correspondent barrel; while, in the mean time, the first mentioned piston being depressed, the air, by its spring, closes the lower valve, and, raising the valve in the piston, makes its escape. The motion of the handle being again reversed, the first barrel again exhausts

exhauſts while the ſecond diſcharges the air in its turn: and thus, during the time the pump is worked, one barrel exhauſts the air from the receiver, while the other diſcharges it through the valve in its piſton.

D Hence it is evident, that the vacuum in the receiver of the air-pump can never be perfect; that is, the air can never be entirely exhauſted: for it is the ſpring of the air in the receiver that raiſes the valve, and forces air into the barrel, and the barrel at each exſuction can only take away a certain part of the remaining air, which is in proportion to the quantity before the ſtroke, as the capacity of the barrel is to that of the barrel and receiver added into one ſum.

E This, however, is an imperfection that is ſeldom, if ever, of any conſequence in practice, becauſe all air-pumps, at a certain period of the exhauſtion, ceaſe to act, on account of their imperfect conſtruction. For the valves uſually conſiſt of a piece of oiled bladder tied over a hole, ſo that the air is at liberty to paſs by lifting up the bladder, but cannot return again, and there will unavoidably be a ſmall ſpace left between the lower valve and the piſton when down. Now, it will happen, when the air in the receiver is very rare, that its ſpring will not be ſtrong enough to overcome the adheſion of the bladder forming the lower valve, which, conſequently, will remain ſhut, and the exhauſtion cannot proceed. Or, before this period, it may happen, that the air between the valves when the

piſton

piston is up may be so small as to lie in the space between the two valves when the piston is down, without being sufficiently condensed for its spring to overcome the adhesion of the bladder forming the upper valve, and the weight of the atmosphere that presses it: in this case the upper valve will remain shut, and the exhaustion cannot proceed. In the best air-pumps these imperfections are in a great degree removed. For the adhesion of the bladders is much diminished, and the action of the air upon them increased, by substituting a number of large holes of passage, instead of one smaller. By causing the rod of the piston to pass through a collar of leathers, screwed to the upper part of the barrel, and placing another valve for the passage of the extruded air, the pressure of the atmosphere is prevented from acting on the piston, so that the whole spring of the air between the piston and lower valve is exerted in overcoming the resistance afforded by the valve of the piston. There are also contrivances for opening a communication between the receiver and the barrel, without depending on the spring of the air. One of the best of these consists in an additional piece that lifts the lower valve when a lever is pressed with the foot: the lever communicates with the interior piece by means of a rod that passes through a collar of leathers at the lower end of the barrel*. The best sort of air-pumps are usually made with a single barrel.

* This is the invention of one ——— Haas, a workman in London, who has taken out a patent for it. Other constructions are given in Nicholson's Journal, by Cuthbertson, Prince, Mackenzie, Clare, &c.

F In measuring the exhaustion there are two methods of proceeding. The one shews the density of the air left in the receiver, without regarding such vapours as may assume an elastic form in the vacuum: the other exhibits the spring of the elastic fluid in the receiver, without shewing whether it be permanently elastic air. The quantity of air is shewn by an instrument called the pear-gage. It consists of a glass-vessel in the form of a pear, with graduations near its upper end, that denote certain known parts of its bulk. This is included in the receiver, together with a vessel of mercury, into which its mouth may be occasionally plunged. When the exhaustion is made, the pear-gage is plunged into the mercury, and the external air admitted into the receiver. The mercury rises in the gage, and occupies the whole of its cavity, except a space at top, possessed by a bubble of air, whose magnitude is known from the graduations, and is in proportion to the whole contents of the gage, as the quantity of air in the exhausted receiver is to an equal volume of the common atmospherical air.

G This gage would be accurate for all purposes, if it were not that most fluid or moist substances assume an elastic form when the pressure of the atmosphere is removed. For this reason it seldom indicates the elasticity or actual pressure of the fluid remaining in the receiver. The barometer gage is used for this purpose. If a barometer be included beneath a receiver, the mercury will stand at the same height

as in the open air; but when the receiver begins to be exhauſted, the mercury will deſcend, and reſt at a height which is in proportion to its former height as the ſpring of the remaining air is to its original ſpring before the exhauſtion. It is uſual to ſay, the air is as many times rarer than the atmoſphere, as the column it ſuſtains is leſs than the height the mercury ſtands at in a detached barometer. On account of the inconvenience of including a barometer in a receiver, a tube of ſix or eight inches length is filled with mercury, and inverted in the ſame manner as the barometer. This being included, anſwers the ſame purpoſe, with no other difference than that the mercury does not begin to deſcend till about three-fourths of the air is exhauſted. It is called the ſhort barometer gage. Others place a tube, of a greater length than the barometer, with its lower end in a veſſel of mercury, while its upper end communicates with the receiver. Here the mercury riſes as the exhauſtion proceeds, and the preſſure of the remaining air is ſhewn by the difference between its height and that of the barometer. This is called the long barometer gage.

Theſe gages are not often conſtructed ſo as to H anſwer the purpoſe of ſhewing the degree of exhauſtion to a great degree. For the mercury, though at firſt boiled, to clear it of the air and moiſture that adhere to it, and render it ſenſibly lighter, gradually becomes again contaminated by expoſure to the air in the baſon of either gage. They cannot therefore with ſtrictneſs be compared

with

with a good barometer in which this does not happen. If the tubes of the gages be leſs than half an inch in diameter, the mercury will be ſenſibly repelled downwards, ſo as to require a correction for the long gage when compared with a barometer, whoſe tube is of a different bore, and to render the ſhort gage uſeleſs in great exhauſtions. Thus, for example, if the ſhort gage have a tube of one-tenth of an inch in diameter, the mercury will fall to the level of the baſon when the exhauſtion is 150 times, and will ſtand below the level for all greater degrees of rarefaction. Theſe difficulties may all be removed, by making the ſhort gage in the form of an inverted ſyphon, with one leg open, and the other hermetically ſealed. It muſt be confeſſed, however, that it is not eaſy to boil the mercury in theſe; and the method of doing it with ſucceſs cannot, with ſufficient conciſeneſs, be deſcribed here.

I Few air-pumps exhauſt to ſo great a degree as one thouſand times by the barometer gage; but the pear-gage in ſome circumſtances will indicate an exhauſtion of many thouſand times.

K Several of the uſes of the air-pump have already been mentioned. The weight of the air is ſhewn by exhauſting it out of a bottle (30, x) and its preſſure is proved to be the cauſe of the aſcent of the mercury in the barometer, becauſe in the vacuum it is no longer ſuſtained. It will be proper to ſubjoin a few more inſtances.

If a ſquare bottle, in whoſe neck is fixed a valve, opening outwards, be placed under the receiver, and the air exhauſted, the bottle will be cruſhed to pieces by the weight of the atmoſphere when the air is permitted to return into the receiver. For the air is prevented from entering the bottle by the valve, which, before the exhauſtion, ſuſtained the preſſure of the atmoſphere on its external ſurface, by means of the ſpring of the included air acting equally on the internal ſurface; but in this eperiment, being deprived of its internal air, it is incapable of bearing the weight of the atmoſphere, which preſſes it on all ſides. If the bottle were round inſtead of ſquare it would ſuſtain the preſſure, notwithſtanding the exhauſtion, by reaſon of its arched figure, that would prevent its giving way inwards. L

The quantity of this preſſure on a given ſurface is equal to the weight of a column of mercury, whoſe baſe is the given ſurface, and whoſe height is the height of the mercury in the barometer (32, B). To exemplify and prove this by the air-pump, it is uſual to incloſe in the receiver two braſs hemiſpheres, as A and B (fig. 149), that ſhut together like a box, and at the place of ſhutting are lined with wetted leather. The air being exhauſted from the receiver, eſcapes likewiſe from the cavity of the hemiſpheres, and when it is permitted again to enter the receiver, the hemiſpheres are ſo cloſely preſſed together, that the air cannot enter at the place of junction: they adhere toge- M

ther,

ther, therefore, with a force equal to the preſſure of the atmoſphere, which is greater or leſs in proportion to the area of the circle at the place of junction. Thus, if the diameter of the circle where the hemiſpheres are joined be four inches, the force required to ſeparate them muſt exceed 230 lb. troy.

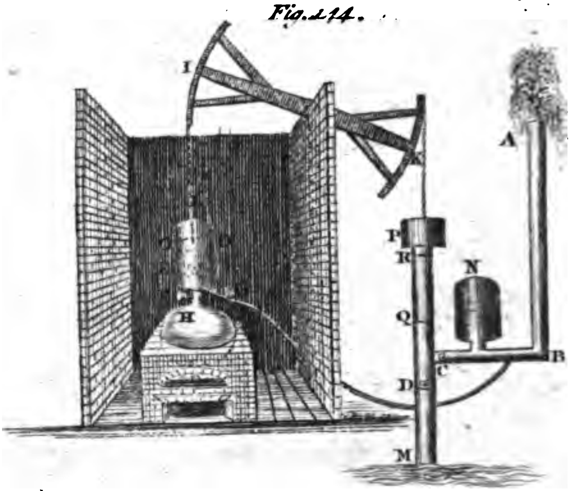
N Since bodies immerſed in fluids loſe parts of their weights, which are equal to the weights of maſſes of the fluids reſpectively equal in bulk to the bodies themſelves (8, Z, A), it follows that bodies of different ſpecific gravities, which are in equilibrio in the air, will not remain ſo in vacuo. For in vacuo each body will re-acquire the weight they loſe while in the air, and the body, whoſe bulk is greateſt, will acquire the greateſt weight. Thus, if a piece of cork be in equilibrio with a piece of lead, when weighed by fine ſcales in the air, the cork will preponderate in vacuo; the removal of the air adding proportionally more to its weight, as its bulk exceeds that of the lead.

O The ſpring of the air may likewiſe be ſhewn in a variety of manners by the aſſiſtance of the air-pump. Suppoſe a ſmall tube to be inſerted through the cork of a bottle, half full of mercury, ſo that the communication between the air included in the upper part of the bottle and the external air ſhall be entirely cut off, the end of the tube being immerſed in the mercury. Let this apparatus be placed under the receiver, and the air exhauſted. The ſpring of the included air then preſſing on the ſurface

N°. 23. Vol. II. face p. 108.

*Engine for raising water by the force of Steam*

*Fig. 114.*




the

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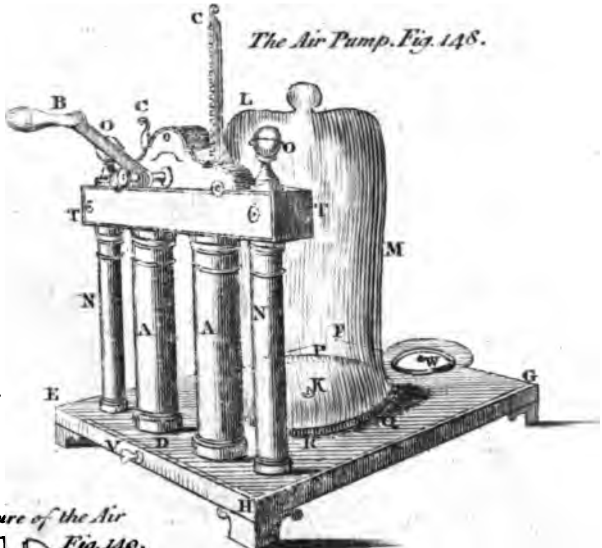
*The Air Pump. Fig. 148.*




*Pressure of the Air*

*Fig. 149.*

surface of the mercury, will force it into the tube, and sustain it at the same height nearly as it stands in the barometer; for the spring of the air is equal to its weight (1. 22, R), and consequently produces an equal effect: but on account of the imperfection of the vacuum, and the expansion of the air in the bottle, by which its spring is weakened, the mercury does not rise exactly as high as it does in the barometer.

If a half blown bladder be placed in the receiver, the included air will expand as the exhaustion proceeds, and will blow it up even to bursting. And if this bladder be inclosed in a box, whose cover is loaded with weights somewhat less than equal to that of the atmosphere, the expansion will raise the cover and sustain the weights. Thus, if the bladder be inclosed in a box of six inches diameter, it will raise the cover, though loaded with upwards of 500 lb. troy (32, B). P

The spring of the air included in the larger pores or vessels of bodies, is the foundation of a number of pleasing and instructive experiments. Thus it is found, that wood is specifically lighter than water, only by reason of the spring of the air included in its vessels, that prevents the water from entering: for when this air is extracted, and the water, by the admission of the external air into the receiver, is impelled into the vessels of the wood, it is always found to sink to the bottom. Q

The refractive power of the air is also shewn by the air-pump. For if the air be exhausted out of a prismatic R

a prismatic glass-vessel, the rays of light will not pass straight through its sides, but in passing through the vacuum, will be deflected according to the established laws of optics. The proportions of the sines of the angles of incidence and refraction, out of the vacuum into the air, are by this means found to be as 100036 to 100000, which is nearly the same ratio as is deduced from the refractions of the heavenly bodies.

S It is likewise proved by the air-pump, that the air is the medium of sound. A bell or small alarm clock, being rung in the exhausted receiver, gives no sound; but if the air be admitted, the sound gradually becomes louder and louder, till the air in the receiver be of the same density with that of the atmosphere, at which time the sound is no otherwise weakened than on account of the receiver that covers the bell.

T The resistance of the air is exhibited in a striking manner by the help of the air-pump; for, if a guinea and a feather be let fall together from the top of a tall exhausted receiver, they both arrive at the bottom at the same instant.

U Among the very numerous instances of the usefulness of this instrument, we shall mention but two more; namely, the discovery of the absolute necessity of air for the preservation of life in most animals, and for the production and continuance of flame. Most animals, when included in the exhausted receiver, are observed to die in about five minutes, though the time is various in different

species;

ſpecies; and they moſtly recover again, if the air be again admitted without being withheld too long. A lighted candle placed under the receiver, is extinguiſhed at the beginning of the rarefaction, and the ſmoke hovers about the top of the receiver; but when the air is ſtill more rarefied, it becomes ſpecifically heavier, and ſubſides to the bottom.

# BOOK III.

## SECT. I.

## Of Chemiſtry.

### CHAP. I.

#### CONCERNING HEAT.

Every change that can take place in bodies is effected by means of motion. The buſineſs of natural philoſophy is to inveſtigate the cauſes of the ſeveral motions, and the laws they follow. In many inſtances theſe motions come under the inſpection of our ſenſes, but for the moſt part they are performed among the minute parts of bodies, and are only known by the effects they produce. The foregoing part of this work has been chiefly confined to the explanation of the former kind of motions, which may be denoted by the general term mechanics. The latter, namely, the effects produced by motions among bodies too minute to affect the ſenſes individually, are the object of a ſcience called chemiſtry.

Heat is one of the moſt important and general cauſes of change in bodies. This term is commonly

monly uſed to denote as well the ſenſation cauſed by an increaſe of temperature in the human body as the ſtate in which inanimate bodies are when their temperature is increaſed. In the following pages, however, it will not be neceſſary to attend to the ſenſation. The word temperature will be uſed to denote the ſtate of a given ſolid, fluid, or vaporous body, with reſpect to heat; and the word heat will be uſed to denote the cauſe of that ſtate.

A body is ſaid to be hot or cold accordingly as its temperature is above or below a given ſtandard. The vulgar make uſe of the temperature of the human body as a ſtandard for this purpoſe. But this is by no means accurate enough for philoſophical purpoſes, becauſe the ſenſations of no two perſons agree, nor even thoſe of the ſame perſon at different times. w

The dimenſions of a body are always increaſed with the temperature, ſo long as the body retains the ſtate of ſolidity, fluidity, or vapour, it happens to poſſeſs, and has ſuffered no change either in the combination or quantity of its chemical principles. This is the chief, and, perhaps, the only general criterion by which the changes of temperature can be appreciated. x

Bodies in contact, or that communicate with each other, will all acquire one and the ſame temperature, after a certain length of time, however different their reſpective original temperatures may have been. y

There are two opinions concerning heat. According to one opinion, heat conſiſts in a vibratory mo- z

tion of the parts of bodies among each other, whoſe greater or leſs intenſity occaſions the increaſe or diminution of temperature: according to the other opinion, heat is a ſubtile fluid that eaſily pervades the pores of all bodies, cauſing them to expand by means of its elaſticity, or otherwiſe. Each of theſe opinions is attended with its peculiar difficulties. The phenomena of heat may be accounted for by either of them, provided certain ſuppoſitions be allowed to each reſpectively; but the want of proof of the truth of ſuch ſuppoſitions renders it very difficult, if not impoſſible, to decide, as yet, whether heat conſiſts merely in motion or in ſome peculiar matter.
A The word quantity applied to heat will therefore denote either motion or matter, according to the opinion made uſe of, and may be uſed indefinitely without determining which.

B Whatever heat may be, it is certainly lawful to affirm, that when the temperatures are the ſame, the quantities of heat are equal in equal bodies of the ſame kind; thus, a pound of gold contains an equal quantity of heat with another pound of gold at the ſame temperature, a pound of water contains an equal quantity of heat with another pound of water at the ſame temperature, &c. Hence it follows, that the quantity of heat in two pounds of a given ſubſtance is twice as much as is contained
C in one pound at the ſame temperature; and univerſally in homogeneous bodies of the ſame kind, the quantities of heat will be as the maſſes, provided the temperatures be the ſame.

If two bodies that differ only in temperature be D
brought into contact, they will (113, Y) acquire a
common temperature, and the quantity of heat in
each will be equal (114, B). It is therefore seen, E
that the hotter body has imparted half its surplus
of heat to the other; and consequently the quantity
of heat in one of the two bodies will be an
arithmetical mean between the quantities originally
contained in them.

If two bodies of the same kind that differ in F
magnitude and temperature be brought into contact,
they will (113, Y) acquire a common temperature,
and the quantity of heat in each will be (114, C)
in proportion to the masses: that is to say, the G
quantity of heat which caused one of the two bodies
to be hotter than the other will be divided between
them in proportion to their masses.

The quantities of heat required to be imparted to, H
or subducted from, bodies of the same kind, in order
to bring their temperature to any given standard,
will consequently be as their masses.

On these considerations it is that the thermo- I
meter is presumed to acquire the same temperature
as the body it touches. For the mass of the thermometer
ought to be very small in proportion to
that of the body it is applied to; in which case the
quantity of heat it gives out or receives in the
acquisition of the common temperature will be so
small as not sensibly to affect the body under consideration;
so that the common temperature may

be taken instead of the original temperature required to be found.

K The arithmetical mean temperature between two equal bodies of the same kind, as determined by experiment (115, E) will cause the mercury in a thermometer to stand very nearly at an intermediate equal distance between the stations it would have had at the original temperatures of the two

L bodies. The increments of expansion in mercury are therefore very nearly as the quantities of heat

M that cause them. And the quantities of heat added to, or subducted from, a given body in contact with a mercurial thermometer, will be expressed by the number of degrees the thermometer rises or falls.

N Thus far the temperature and heat of bodies of the same kind have been chiefly considered; but if two equal bodies of different kinds and temperature be brought into contact, the common temperature will seldom, if ever, be the mean between

O the two original temperatures; that is to say, the surplus of heat in the hotter body will be unequally divided between them, and the proportions of this surplus retained by each body will express their respective dispositions, affinities or capacities for heat.

P If therefore a given substance, as for example fluid water, be taken as the standard of comparison, and its capacity for heat be called one, or unity, the respective capacities of other bodies may be determined by experiment, and expressed in numbers in the same manner as specific gravities usually are.

And

And becauſe it is eſtabliſhed, as well from reaſon Q
as experiment, that the ſame capacity for heat obtains in all temperatures of a given body, ſo long as its ſtate of ſolidity, fluidity, or vapour, is not changed, it will follow, that the whole quantities of heat in equal bodies of a given temperature will be as thoſe capacities. And as the reſpective quan- R
tities of matter in bodies of equal volume give the proportions of their ſpecific gravities, ſo the reſpective quantities of heat in bodies of equal weight and temperature give the proportions of their ſpecific heats.

A greater capacity for heat, or greater ſpecific S
heat in a given body, anſwers the ſame purpoſe with reſpect to temperature as an increaſe of the maſs; or (115, H) the quantity of heat required to be added or ſubducted, in order to bring a body to a given temperature, will be as its capacity or ſpecific heat (117, R).

The capacities not only differ in various bodies, T
but alſo in the ſame body, accordingly as it is either in a ſolid, fluid, or vaporous ſtate. All the experiments hitherto made conſpire to ſhew, that the capacity, and conſequently the ſpecific heat, is greateſt in the vaporous, leſs in the fluid, and leaſt in the ſolid ſtate.

The quantity of heat that conſtitutes the differ- U
ence between the ſeveral ſtates may be found in degrees of the thermometer. Thus, if equal quantities of water at 162°, and ice at 32° of temperature, be mixed, the ice melts, and the common

temperature becomes 32°; or otherwise, if equal quantities of frozen and of fluid water, both at the temperature of 32°, be placed in a like situation to acquire heat from a fire, the water will become heated to 162°, while the ice melts, without acquiring any increase of temperature. In either case the ice acquires 130° of heat, which produces no other effect than rendering it fluid. Fluid water therefore contains not only as much more heat than ice, as is indicated by the thermometer, but also 130°, that is in some manner or other employed in giving it fluidity. And as fluid water cannot become ice without parting with 130° of heat, besides what it had above 32° in its temperature; so also steam cannot become condensed into water without imparting much more heat to the matters it is cooled by than water at the same temperature would have done.

v The heat employed in maintaining the fluid or vaporous form of a body, has been called latent heat, because it does not affect the thermometer.

w From the consideration of the specific heats, of the same body in the two states of solidity and fluidity, and the difference between those specific heats, a method has been proposed of finding the number of degrees which denote the temperature of any body immediately after congelation, reckoned from the natural zero, or absolute privation of heat. The rule is; multiply the degrees of heat required to reduce any solid to a fluid state by the number expressing

the

the ſpecific heat of the fluid: divide this product by the difference between the numbers expreſſing the ſpecific heat of the body in each ſtate; the quotient will be the number of degrees of temperature, reckoned from abſolute privation of heat*.

To give an example of this curious rule, let it be required to determine how many degrees of refrigeration would abſolutely deprive ice of all its heat? The degrees of heat neceſſary to melt ice are 130,

* This theorem is Dr. Irvine's, and may be proved thus; let s repreſent the required temperature of the body juſt congealed, l = the number of degrees that expreſs the heat required to reduce it to fluidity, n = the ſpecific heat of the ſolid, and m = the ſpecific heat of the fluid. Then, $s + l : s :: m : n$. Whence $s = \frac{l\,n}{m-n}$ = the temperature from the natural zero in thermometrical degrees of the fluid (117, v). But becauſe the actual fall of the thermometer is to be produced by cooling the ſolid, we muſt pay attention to its capacity (117, s). The quantity of heat required to produce a given change of temperature in a body is as its capacity, and conſequently the changes of temperature, when the quantity of heat is given, will be inverſely as the capacities: therefore $n : m :: \frac{l\,n}{m-n} : \frac{l\,m}{m-n} = s$. Which is the rule given in the text.

If the data l, m, and n, be accurately obtained by experiment in any one inſtance, and the difference between the zero of Fahrenheit's ſcale and the natural zero be thence found in degrees of that ſcale, this difference will ſerve to reduce all temperatures to the numeration which commences at the natural 0. So that s being known in all caſes, if any two of the quantities l, m, or n, be given in any body, the other may be likewiſe had. For $l = \frac{s\,m - s\,n}{m}$. And $m = \frac{s\,n}{s-l}$. And $n = \frac{s\,m - l\,m}{s}$.

and the ſpecific heats of ice and water are as 9 to 10. The number 130, multiplied by 10, produces 1300, and divided by the difference between 9 and 10 quotes 1300: therefore if ice were cooled 1300 degrees below 32°, or to — 1268 of Fahrenheit's ſcale, it would retain no more heat.

Z It is unneceſſary to point out the many phyſical cauſes that prevent either the production or menſuration of this ultimate degree of cold.

A Experiments on heat may be made by mixing fluid bodies, by placing them in a vaſe, whoſe temperature, volume, and ſpecific heat or capacity are known; or by placing them in contact with ice at 32°; in which laſt caſe, the quantity of ice melted by a body hotter than 32° will be in proportion to the quantity of abſolute heat that cauſes this difference of temperature.

B Much care is required to prevent occaſional circumſtances from influencing the reſults of theſe experiments. The maſſes, ſpecific heats, and temperatures of the veſſel and thermometer made uſe of, as well as the temperature of the ſurrounding atmoſphere, muſt be attended to. The thermometers muſt be very ſenſible, and give the temperature to tenths of degrees. The temperature of the mixture muſt be taken in various parts of the veſſel, and its rate of cooling aſcertained at different periods, in order to infer the common temperature that would have taken place if the ſurplus of heat could have been equally diffuſed at the firſt inſtant of the mixture. When the melting of ice

is

is made use of, it is necessary that the ice exposed to the contact of the heated body should be defended from the action of the external air, by being included in a vessel surrounded on all sides with other ice at 32°, and the temperature of the room ought not to be much colder than 32°, lest the melted ice should be again frozen, instead of running into the vessel prepared to receive it.

The chief advantage which the opinion that heat C
is caused by mere vibration possesses, is its great simplicity. It is highly probable that all heated bodies have an intestine motion or vibration of their parts; and it is certain that percussion, friction, and other methods of agitating the minute parts of bodies will likewise increase their temperature. Why, then, it is demanded, should we multiply causes, by supposing the existence of an unknown fluid, when the mere vibration of parts, which is known to obtain, may be applied to explain the phenomena?
To this it is answered, that mere motion will not D
apply to the phenomena: for, among other facts, water at 32° contains more heat than ice at 32°, and ought therefore to possess more vibration, yet it does not communicate more to the thermometer. A part of its motion must consequently be latent or incommunicable, which seems to be an absurdity.

A happy explanation of the manner in which the E
temperature of a body is raised by friction or percussion, has been given * on the supposition that heat is matter. If the parts of a body containing any

* By Mr. Kirwan.

fluid

fluid be made to vibrate strongly and irregularly, they will expel a part of the fluid out of the pores, provided the fluid be not sufficiently compressed to move in correspondence with the vibrations. For in this case a vibrating particle may be considered as if its dimensions were increased, which is in effect the same thing as if the pores of the body were diminished. The capacity of the body will thus be diminished, and consequently its temperature will be increased (117, s).

F All the changes of temperature from the most intense cold to the utmost violence of ignition may be explained from the changes the capacities of bodies, and consequently their specific heats,
G undergo in the several chemical processes. For universally, whenever the capacities of bodies are diminished, either by freezing or condensation, (117, T), by friction or percussion (121, E), or by a change in the chemical combination, then the temperature is increased (117, s). And on the contrary, the temperature is diminished, or bodies become cold whenever their capacities for heat are increased.

H Thus, in the solution of various saline bodies in water, cold is produced; because the capacity of the salt being increased (117, T) by its becoming fluid, while the absolute quantity of heat remains the same, its temperature must be diminished (117, s). Consequently, the common temperature of the melted salt and water must be lower than it would have been if the salt had not been dissolved (113, Y).

For the ſame reaſon a mixture of ſnow and ſalt, I
applied at the outſide of a veſſel containing water, produces a degree of cold that congeals the water, or would cauſe a thermometer to fall far beyond the freezing point. The ſnow and ſalt are rendered fluid by their mutual action on each other; their capacities for heat are increaſed, their temperatures conſequently diminiſhed, and the water frozen by the loſs of the heat it imparts to produce a common temperature.

So likewiſe, if a ſmall glaſs veſſel, containing K
water, be conſtantly wetted on the outſide with ether, the quick evaporation of this laſt fluid will produce a degree of cold that will in a very ſhort time freeze the included water. For the ſpecific heat of the ether, when converted into vapor, is ſo great, that its temperature becomes very low, and cools the water even below freezing.

The inſtances of cold produced by evaporation L
are exceedingly numerous. From this cauſe it is that water is commonly about two degrees colder than the ſurrounding air; that damp clothes produce ſuch chilling effects; that a wet hand, even though wetted with warm water, ſoon becomes colder than the other that remains dry, &c. &c.

The ſpecific heat of atmoſpherical air is found M
by experiment to be conſiderably greater than that of air which is expired from the lungs of an animal. The air therefore undergoes a change in the lungs, which diminiſhes its capacity, and muſt conſequently increaſe its temperature. It is found alſo, that

the

the capacity of blood for heat is diminiſhed in its courſe from the arteries to the veins. From theſe cauſes the temperature of the animal is continually increaſed. But the evaporation of perſpirable matter increaſes with the temperature, and produces cold. The equilibrium of theſe actions appears to be the reaſon why the temperature of any one ſpecies of animal is nearly the ſame in all climates. Animals that have no lungs are of the ſame temperature as the ſurrounding medium. In cold countries the effects of perſpiration, and the contact of the circumambient air, are rendered leſs by the clothing, as thick fur, hair, &c. that envelope the native animals, and are from neceſſity made uſe of by the human ſpecies.

N The ſpecific heat of combuſtible matter is not conſiderable; the ſpecific heat of atmoſpheric air is much greater than that of air which has ſerved the purpoſe of combuſtion. Suppoſe now that by any means the temperature of a combuſtible ſubſtance be raiſed to ſuch a degree as that the chemical proceſs, which changes the capacity of the air, may go on, the temperature of the air will be raiſed in proportion as its capacity is diminiſhed, its heat will be imparted to, and ſtill more increaſe, the temperature of the combuſtible body. A very high degree of temperature will be produced, which will be greater in proportion to the ſpecific heat of the air, the quantity decompoſed in a given time, and leſs in proportion to the facility with which it is abſorbed or conducted away

by other bodies. This procefs is called combuftion, when it is carried on with fuch rapidity as to caufe the body to emit light, at which time it is faid to be ignited; and it will continue till the principles of the body are fo changed or diffipated as that it can no longer make any change in the capacity of the furrounding air.

The friction of one piece of wood againft an- o other, in a turner's lathe, produces heat and flame. A nail may be hammered till it becomes red hot. When flint and fteel are ftruck together, minute portions of the fteel are knocked off, in fo high a degree of heat, that they are actually burned, and upon extinction are feen, with the magnifier, to confift moftly of hollow balls of a black or greyifh metallic colour, and about the one hundredth of an inch in diameter. When the fun's rays are thrown, by a burning-glafs or mirror (I. 325, N), on any fubftance, they exceedingly increafe its temperature, and produce the moft aftonifhing effects. In all thefe phenomena the temperature feems to be raifed, at leaft in the beginning, by the diminution of capacity, which is a confequence of the agitation of the minute parts of bodies.

When water, or any fluid, is heated, the quan- P tity evaporated in a given time becomes greater, becaufe the heat which the greater capacity of fteam demands is more readily fupplied. The greater evaporation diminifhes the augmentation of temperature the fluid acquires, and at a certain period entirely deftroys it. This period or tempera-

ture,

ture, called the boiling point, is lower, the more easily evaporable the fluid, and will vary in the same fluid, accordingly as the evaporation is more or less easily performed. Thus spirit of wine boils at 180°, water at 212°, mercury at 600, and other liquids at other points respectively, at which they acquire the greatest heat they are capable of sustaining without being converted into vapor in the open air of a mean density. But if the evaporation be impeded, either by the fluid being included in a closed vessel, or by the increased pressure of a denser atmosphere, the fluid will acquire a higher temperature: and, on the contrary, if the atmosphere be light, or the fluid heated in vacuo, the boiling temperature will be lower *.

* The Theory of heat, as here explained, is due to the immortal Dr. Black, and has been improved and illustrated by Dr. A. Crawford, Dr. Irvine, Mr. Kirwan, Professor Wilkie, Mr. Watt, Mr. Magellan, &c.

CHAP.

## CHAP. II.

### A DESCRIPTION OF THE METHODS OF APPLYING HEAT TO CHEMICAL PURPOSES.

There are few ſubſtances found in a natural Q
ſtate whoſe conſtituent parts cannot be ſeparated
from each other by the methods uſed in chemiſtry,
One of the principal methods conſiſts in altering
the temperature of bodies.

A great number of bodies are found to be R
capable of the ſolid, the fluid, and the vaporous
or highly elaſtic form, accordingly as they contain
leſs or more heat. The temperature at which
ſolids become fluid is exceedingly various in different
ſubſtances, as is likewiſe the temperature at
which the internal parts of fluids begin to take
a vaporous form, and eſcape with ebullition.
The number of degrees of temperature comprehended
between theſe two points of freezing and
boiling is not governed by any relation yet diſcovered
between theſe phenomena and the other
properties of bodies. Thus mercury freezes at
49° below 0, and boils at 600°; the interval
being 649°; water freezes at 32°, and boils at 212°,
the interval being 180°; alcohol or ſpirit of wine
freezes at 52° below 0, and boils at 180°, the interval
being 232°. It is probable that all bodies S
whatſoever are capable of the three ſtates of ſolidity,
fluidity, and vapor; but that in many inſtances

the

the freezing or boiling points may lie at temperatures not obtainable by any means in our power.

T Bodies that aſſume the vaporous ſtate at a lower temperature are called volatile, when compared with ſuch as require a greater degree of heat for the ſame purpoſe. Such bodies as either cannot be made to riſe in vapor, or require an intenſe heat to raiſe them, are called fixed.

U It is eaſy to conceive how the parts of bodies may be ſeparated from each other by change of temperature. Thus, if ſoap be diſſolved in alcohol of wine, and the temperature be rendered lower, the ſoap will aſſume a concrete form, and be ſeparated long before the fluidity of the alcohol can be affected. Water mixed with alcohol is converted into ice by cold, and ſeparated for the ſame reaſon. Again, if a mixture of copper and lead be expoſed to a heat gradually increaſed, the lead will be melted firſt, and will run from the copper, leaving it in the form of a porous maſs: or if braſs, which is a mixture of copper and a volatile ſemi-metal called zink, be expoſed to a conſiderable heat, the zink aſſumes the vaporous ſtate, and leaves the copper alone. So likewiſe quickſilver is ſeparated from gold, water from clay, &c.

V The purpoſes of chemiſtry are in general much better anſwered by raiſing than by lowering the temperature of bodies. The moſt uſual method of heating bodies is, to place them in communication with others in a ſtate of combuſtion; that is to ſay, place them near a fire. The veſſels and

furnaces made uſe of are various, according to their ſeveral applications.

When ſubſtances of conſiderable fixity are to be expoſed to heat, or when the volatile parts of bodies are propoſed to be diſſipated into the air, open veſſels are uſed. The common culinary utenſils of copper or iron anſwer theſe intentions where the matter to be operated upon will not corrode them, and the heat is not required to be very great. Glaſs veſſels are the moſt cleanly, and may be uſed in a great variety of proceſſes. They have the advantage of reſiſting the action of moſt corroding matters, are impermeable to air and vapour, and their tranſparency affords the valuable convenience of beholding the changes that happen within them. In higher degrees of heat, ſuch as would ſoften or melt glaſs, it is neceſſary to uſe veſſels of earth, or other matter.

A mattras, is a kind of bottle, ſhaped moſt commonly like a Florence flaſk, though its figure is various, according to the uſes it is intended to be applied to, fig. 150. A cucurbit, is a veſſel nearly of the ſame figure, but with a long neck; it is made either of metal, glaſs, or earthen-ware. Crucibles are pots made uſe of for melting metal and other ſimilar purpoſes; they are made either of platina, ſilver, forged iron, black lead, earthen-ware, or porcellain. The larger crucibles are generally conical, with a ſmall ſpout, or lip, for the convenience of pouring out the melted matters, fig. 151. The ſmaller crucibles are truncated triangular pyramids, fig. 152. Others

are conical, but ſwelling out in the middle, fig. 153. The black lead crucibles are very durable, but they cannot be uſed for alcaline ſubſtances. A cupel, is a ſhallow crucible, or cup, made of calcined bones, and uſed by aſſayers, fig. 154. The large crucibles of this kind, uſed by refiners, are called teſts, fig. 155.

Y In moſt operations where the volatile parts of bodies are propoſed to be ſeparated and preſerved, it is neceſſary to uſe cloſed veſſels. To the cucurbit fig. 150, and 156. No. 25. is adapted the head B; from this head proceeds a tube that communicates with the mattras C, which in this caſe is called the receiver. The whole apparatus thus diſpoſed is called an alembic or ſtill.

Z When diſtillation is performed in the large way, the ſtill, fig. 157, is made uſe of. A is the body of the ſtill, B the head, D the worm-tub containing cold water.

A Diſtillation may alſo be performed by means of the retort and receiver. The retort, fig. 158, is a globular veſſel, either of glaſs or earthen-ware, with a neck extending in a curved direction, terminating in an open point or mouth. The materials to be diſtilled are introduced into the body of the retort, and heat is applied to cauſe the ſubſtance to boil. To the neck of the retort is adapted a receiver, wide enough to allow the neck of the retort to be introduced into it. It is intended to receive from the retort, the fluid that diſtills over. Fig. 159, is a tubulated retort, which merely differs from the former by having an opening, which may be cloſed with a ground ſtopper in the upper part or roof of the retort.

tort. Fig. 160, is a hydroftatic funnel for pouring fluids gradually into air-tight veffels, efpecially when attended with the formation of gas. It is evident that any portion of fluid poured into the funnel x, more than fufficient to fill the two firft parts of the bent tube up to the level z, will efcape by the lower extremity B. At the fame time no gas can return through this funnel, unlefs its preffure be able to overcome the refiftance of a column of fluid of the height of x y. Fig. 161, is another contrivance for the fame purpofe. It confifts of a common glafs funnel, in the throat of which is inferted a glafs rod with a conical point, which regulates the paffage of the fluid through the funnel, according to the firmnefs with which it is fcrewed in.

When volatile fubftances are raifed by heat in a dry form, the procefs is called fublimation. If the fublimed mafs has a loofe powdery form, it is called flowers. Such are the flowers of brimftone, of benjamin, &c. An ordinary cucurbit, or mattras, will ferve for the fublimation of fuch bodies as are not very volatile. When they are more volatile, the head B of the alembic is a proper receptacle, fig. 156, efpecially if moift products arife and are required to pafs at the fame time into the receiver c. In other cafes the receiver is not annexed, and a number of heads are fixed one above the other communicating by necks, the uppermoft one only being clofed at the top. Many fublimates are attached to the chimnies of furnaces, among which common foot is a familiar inftance. B

The conftruction of furnaces is as various as the purpofes they are defigned to ferve. C

D Fig. 162, repreſents the wind-furnace, or air melting furnace. In this ſection A denotes the aſh-hole, B the grate, C a crucible placed on the grate, F a ſtone covering the upper part of the fire-place. The fuel and pots are introduced at the hole F. The effects of this furnace are eaſily explained. Combuſtion is more rapid and intenſe in proportion to the quantity of air ſupplied and decompoſed. The preſſure of the atmoſphere upwards is greater than the preſſure of the column that acts downwards, becauſe the lower part of this laſt mentioned column conſiſts of a rarefied portion of air included in the chimney. The lighter column will therefore aſcend with a velocity ſo much the greater as its rarefied part is longer and more rarefied. If therefore the fire be large, and the chimney high and ſufficiently narrow for the air to paſs through before it is much cooled, a very powerful degree of heat will be produced.

E Fig. 163, is an improved chemical lamp furnace, with double concentric wicks, very convenient for almoſt every operation of chemiſtry *. It conſiſts of a braſs rod ſcrewed to a foot of the ſame metal. On this rod ſlide three braſs ſockets with ſtraight arms, terminating in braſs rings of different diameters. Theſe rings ſerve for ſupporting glaſs retorts, evaporating baſons, Florence flaſks, &c. for performing diſtillations, digeſtions, ſolutions, evaporations, ſaline fuſions, concentrations, analyſis with the pneumatic apparatus, &c. If the veſſels are not wiſhed to be

* See Nicholſon's Journal of Natural Philoſophy, &c. 1804, No. 32, page 266.

exposed

exposed to the naked fire, a copper sand-bath may be interposed, which is to be previously placed in the ring. Each of these brass rings may, by means of a thumb screw acting on the rod of the lamp, be set at different heights, or turned aside according to the pleasure of the operator. Below these rings is a fountain lamp on Argand's plan; this lamp also slides on the main brass rod by means of a socket and thumb-screw. It is therefore easy to bring it nearer or to move it farther at pleasure from the vessel which may remain fixed, a circumstance which, independent of the elevation and the depression of the wicks of the lamp, affords the advantage of heating the vessels by degrees after they are duly placed, as well as of augmenting or diminishing the heat instantly, or for maintaining it for several hours at a certain degree, without in the least disturbing the apparatus connected with it. It may therefore be used for producing the very gentle heat necessary for the rectification of ethers, or the strong heat requisite for distilling mercury. The chief advantage of this lamp consists in its power of producing an intense heat, by the addition of a second cylinder added to that of the common lamp of Argand's. This additional cylinder incloses a wick of one inch and a half in diameter, and it is by this contrivance that a double flame is caused, and more than three times the heat of an Argand's lamp of the largest size is produced.

There are many other furnaces, for the making of glass, the roasting of ores, and extracting their contents, the firing of pottery, and other numerous pur-

 poses.

poſes. For the deſcription and uſe of theſe, larger treatiſes muſt be recurred to *. The philoſophical chemiſt may in general perform his operations without being under the abſolute neceſſity of uſing furnaces conſtructed on purpoſe, or preparing any large apparatus of veſſels. A tobacco-pipe is a very uſeful kind of crucible, with which many experiments may be well made in a common fire, eſpecially with the aſſiſtance of a pair of double bellows. Common chafing diſhes, ſmall iron ſtoves, or the larger kind of black lead pots may be applied to purpoſes of the moſt extenſive utility by an ingenious operator. Bottles of various ſhapes, and other veſſels, may be found in common uſe well ſuited to the performance of chemical experiments: ſuch are apothecaries phials, Florence flaſks, earthen pans, &c.

G The blow-pipe is an inſtrument of great uſe in the chemical examination of mineral bodies. This may be procured in the ſhops.

H The common blow-pipe is ſubject to two principal inconveniences; the firſt is, that the moiſture of the breath becomes condenſed in the tube, and occaſionally ſpirting out of the aperture, either checks the burning of the flame, or produces other diſagreeable accidents; the other is, that the aperture being invariable, can only be adapted to a flame of one particular magnitude, whereas a larger flame requires a larger aperture. The blow-pipe beſt ſuited to philo-

* A deſcription and drawing of a very convenient portable univerſal chemical furnace may be ſeen in the 24th Number of the Journal of Natural Philoſophy, Chemiſtry, and the Arts.

sophical purposes, fig. 164, consists of a tube about 10 inches long. The aperture A is about $\frac{1}{4}$ of an inch in diameter, and is intended to be applied to the mouth in blowing; the other aperture B is very small, so that the air issues out of it in a stream; it is provided with a ball, C, in which the vapours are detained, instead of passing through the aperture B. If, now, a candle be snuffed and the wick turned a little on one side, the flame may by this stream of air be directed upon any small body, and is sufficiently active to produce every change that the strongest furnace can effect on larger bodies.

The body to be urged by the flame, directed and I
excited by a blow-pipe, ought not to exceed the size of a grain of pepper. The best supporter to place it on is a smooth close piece of charcoal, which answers perfectly well for all matters that do not sink into its pores, nor are changed by it. In such cases as the charcoal cannot be used, it is necessary to be provided with a small spoon, either of pure gold or pure platina.

The advantages attending experiments made with K
the blow-pipe are many. They may be made in a very short time in any place, by an apparatus that admits of being carried in the pocket. The quantity required of any material is so small, that they are performed at a very little expense. And the whole process, instead of being carried on in an opake crucible, is visible from beginning to end. They are therefore of great utility in examining bodies where experiments in the large way cannot easily or conveniently be made,

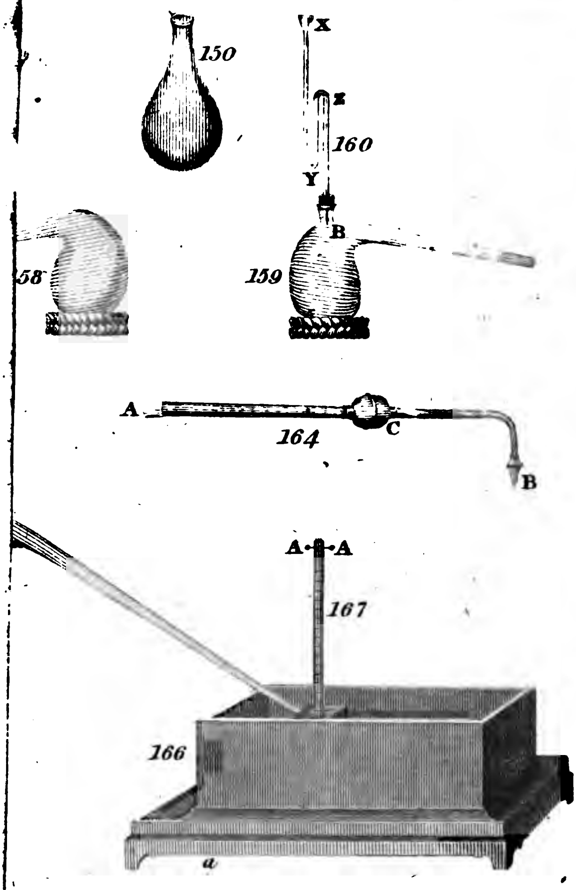
and where they can, theſe ſmall trials previouſly made are often of ſervice to indicate the beſt way of conducting them *.

The burning glaſs or mirror is ſeldom uſed in chemiſtry, except on ſuch occaſions as do not admit of the other methods of heating bodies.

Fig. 165, is a metallic veſſel for boiling inflammable fluids, A, B, C, D, is the body of the kettle, D a long ſpout proceeding from it for preventing any riſk of boiling over; E is a ſhort ſpout for pouring out. The veſſel ſhould not be filled above F, and the long ſpout D ſhould be placed ſo as to be as little heated as poſſible. When the fluid begins to ſwell and boil up, both from the great increaſe of ſurface, and from part of it running up the cooler ſpout D, the ebullition will be checked, and all danger of running over be prevented.

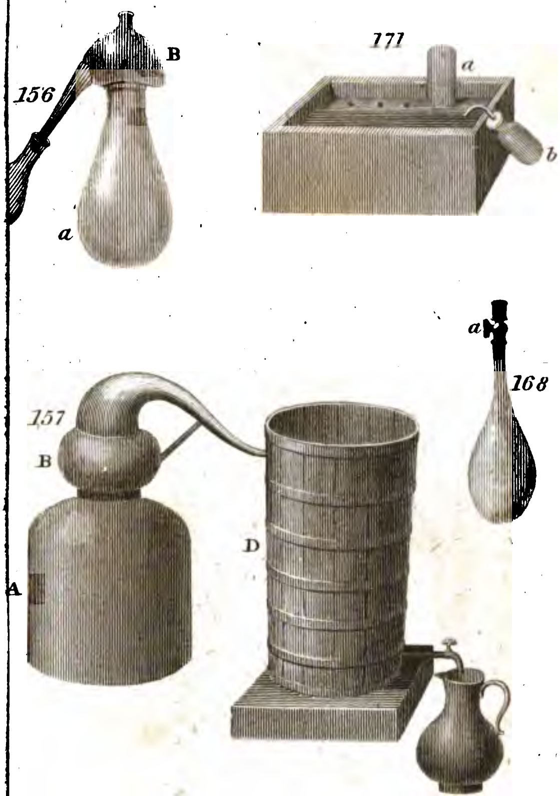
* A ſelf-acting blow-pipe may be ſeen deſcribed and figured in the ſecond volume of Accum's Chemiſtry.

CHAP.




I. Roffe del. et sc.

No. 25, Vol. II to follow pl. 24.




I. Rossé del et sc.

# CHAP. III.

## NATURE AND EFFECTS OF ATTRACTION, OR CHEMICAL AFFINITY.

It has been ſufficiently ſhewn in the former parts A
of this Treatiſe, that the parts of bodies have a tendency towards each other, which is generally denoted by the word Attraction. Were it not for the effects of this power, the motions of all bodies would be performed in right lines (1, 21, P), and their parts would be ſeparated from each other by the ſmalleſt impulſe. It is, in fact, impoſſible to form a notion how the univerſe could ſubſiſt in its preſent form without it.

The firſt rule of philoſophizing (1. 6) leads us B
to enquire whether the various effects of attraction that take place in natural phenomena be conſequences of one and the ſame principle, or, if more cauſes than one ſhould be concerned in producing them, how far the operation of each extends. If the attraction of coheſion were the ſame as gravitation, its power would follow the ſame ratio of the diſtances of bodies from each other (1, 207), and would be ſenſible at very conſiderable intervals of ſpace; but as it
is perceived only at extremely ſmall diſtances, and C
even gives place to repulſion when the interval is increaſed (1. 47, Z), it ſeems neceſſary to conſider it as

a diſ-

a diſtinct property of matter, or, at leaſt, as the effect of ſome other cauſe.

D Whether the attraction of coheſion, or the power that reſiſts the ſeparation, by mechanical means, of the parts of ſolid bodies, be the ſame as thoſe attractions which, on account of their being exerted more ſtrongly between two given bodies, than between one of the two and a third of a different kind, (called elective attractions, or chemical affinities,) has not been well decided. The enumeration of a few ſimple propoſitions reſpecting attraction, generally conſidered, may tend much to elucidate this buſineſs.

E As the attraction of gravitation is taken to be a general property of matter, acting according to the maſſes of bodies (I. 18. 1; 26, A), and we do not ſuppoſe a variety of attractions, but of denſities, in bodies that are variouſly heavy, ſo may one general property cauſe the particles of bodies to adhere together, though its intenſity, varying with the denſity of thoſe particles, may produce various effects.

F In all the phenomena of attraction, the force is greater when the diſtance is leſs: and it is clear, that particles of the ſame maſs and denſity may have various figures, ſome of which will admit of a nearer approach of their centers, when their ſurfaces are in con-
G tact, than others. Such particles as by their figure can admit of their centers coming nearer together, will adhere more ſtrongly on that account.

H Againſt the truth of the poſition, that the attractions diſplayed in the coheſion of bodies, and in chemical

chemical operations, follow the denſity of the particles, it is no objection to ſay, that the hardneſs and ſpecific gravity of bodies are governed by no common law: for the hardneſs, according to this doc- I
trine, depends on the denſity, magnitude, and figure of the particles, and the ſpecific gravity on the denſity of the particles, and the proportion between their aggregate bulk and the bulk of the ſpace occupied by the pores of the bodies. And as theſe attributes K
do not depend on each other, but may vary indefinitely, there is no neceſſary relation between hardneſs and ſpecific gravity.

The adheſion of like parts, by which a body is L
formed of the ſame kind as the parts themſelves, is called aggregation; but the adheſion of parts, not of the ſame kind as each other, by which a body is formed, having properties different from thoſe of the parts, is called combination, or affinity of compoſition.

Affinity of compoſition is regulated by the follow- M
ing laws.

*It takes place only between different bodies, either ſimple or compounds, and unites them into one whole, whoſe properties are different from the original conſtituent parts.* For inſtance, 8 parts of biſmuth, 5 of lead, and 3 of tin, when melted together, form an alloy which melts in boiling water.

*Affinity of compoſition is oppoſed by the attraction of* N
*aggregation.* If we pour ſulphuric acid upon a ſolid piece of fluor ſpar, no perceptible action takes place, but if we reduce the ſpar to powder, and then preſent

it to the acid, a violent action instantly takes place; so that chemical affinity is opposed by that of aggregation.

O *It is always accompanied by a change of temperature.* If sulphuric acid and water be mingled together, in the proportion of 4 parts of the former and 1 of the latter, the temperature of the mixture will be about 300°. If equal parts of muriate of ammonia, nitrate of potash, and water be mixed together, the cold produced will be about 36°.

P *The agency of chemical affinity is different in different bodies.* If we pour nitric acid upon silver, the acid will combine with the silver by virtue of chemical affinity, and form a chemical compound consisting of silver and nitric acid; if we present to this compound, copper, the nitric acid will abandon the silver and go to the copper, the solution now will be a compound, consisting of nitric acid and copper, for the silver will be separated in its metallic state. If we add to this new compound, iron, the nitric acid will quit the copper and go to the iron, and the copper will be precipitated. If zinc be presented to this solution of iron, the zinc will be dissolved, and the iron become separated, &c.

Q *The agency of chemical affinity is modified in proportion to the ponderable quantities of the acting bodies.* If we boil together in a small quantity of water, equal parts of potash and sulphate of barytes; the sulphuric acid will be divided between the barytes and the potash, in the compound ratio of their mass. The greatest part of the sulphate of barytes will remain undecomposed,

posed, most of the potash will also be unaltered, but a certain quantity of barytes will be decomposed, a portion of pure barytes will be found, and a portion of sulphate of potash will also be found, originating from the sulphuric acid, which the sulphate of barytes lost, and the sulphate of potash which suffered decomposition. Hence it becomes obvious, from this law, which was first noticed by Bertholett, then speaking of the different affinities of different bodies, that substances ought to be considered as always acting in certain determinate proportions. For the excess of quantity is capable in most cases to compensate for the deficiency of the force of affinity; so that by varying this, the effect will be varied. The tables of elective affinity, as they have been called, laid down in different books, must be therefore considered as presenting useful rather than accurate approximations to the true nature of relative affinity.

The attractions which tend to preserve the original arrangement of two or more bodies, are called *quiescent affinities:* those whose tendency is to destroy the original compound, are termed *divellent affinities.*

By the term of *disposing affinity*, is meant, by some authors, the tendency which certain bodies have to combine, by virtue of the addition of another body, which frequently exerts no affinity to any of them in a separate state. If phosphorus and water, or phosphorus and potash, or potash and water, are brought in contact with each other, and heat be applied, neither of the substances will act upon each other; the water as a compound body will undergo no change,

but

but if all three bodies be preſented to each other, under the ſame circumſtance, the water will be decompoſed, the ſubſtances will act upon each other, and a total new arrangement of principles will take place. The affinities of different bodies may, therefore, lie dormant until called into action by the interpoſition of another body. But it ſeems abſurd to ſuppoſe that a body can poſſeſs affinities before it is formed; and when this, and the before-mentioned law of affinity are more attended to, they will probably lead to explanations of the greateſt importance to chemiſtry.

T When ſimple bodies combine together, the compound reſulting from that union is called, a primary compound. When two, three, four, or more ſimple bodies combine, the compound is termed, a binary, ternary, quaternary, &c. compound. For inſtance, if we melt together ſulphur and copper, the compound is a binary compound; if we add zinc it is called a ternary compound, &c.

U When principles are combined in ſuch proportions as to form a compound that exhibits the leaſt poſſible of any of the diſtinguiſhing properties of the principles, they are ſaid to be ſaturated with each other. If either principle exceed this proportion, it is ſaid to be imperfectly or partially ſaturated, and the other is ſaid to be ſuperſaturated.

For example, if muriatic acid, be added to ſoda, the compound will exhibit acid properties, if the firſt abound beyond a certain proportion; or if the latter predominate, the alkaline properties will prevail; but

if each be in due quantity, the compound will be common culinary ſalt, neither acid nor alkaline.

Mixture is the union of principles, which remain neverthelefs in conſiderable maſſes that adhere to each other reſpectively, either by reaſon of the ſimilar principles having a greater attraction to each other than to the principles of another kind, or becauſe the conditions are not ſufficient (141, T) to cauſe that change which would produce an intimate combination of the whole. X

Oil and water, when ſhaken together, do not combine but only mix, becauſe the parts of each reſpectively attract thoſe of the ſame kind more ſtrongly than the other: ſo likewiſe potaſh and ſand may be mixed without combining, but an increaſe of temperature in the furnace of a glaſs-houſe will cauſe them to unite, and form the combination called glaſs. Y

When a fluid combines with another body without loſing its fluidity, this laſt is ſaid to be held in ſolution, or diſſolved, and the fluid is called a ſolvent or menſtruum. Z

A menſtruum ſaturated with one principle may, notwithſtanding, take up another (139, N, O). A

Thus ſalt may be diſſolved in water, and when it is ſaturated, and will not act on ſalt, it will diſſolve ſugar.

When a fluid that holds one or more principles in ſolution lets one fall upon the addition of ſome new body to which the combination has a greater affinity, the principle let fall is ſaid to be precipitated by the newly added ſubſtance, which is called the precipitant. B

Epſom

Epsom salt consists of magnesia, combined with sulphuric acid. If this salt be dissolved in water, and carbonate of potash be added, the magnesia will fall to the bottom in the form of a white powder, and the potash will combine with the sulphuric acid.

C When two principles are so separated on the addition of a third, that one of the original principles quits the other, and forms a new combination with the third, the decomposition and new combination are said to be produced by simple affinity.

D Common salt, as has been already observed, is a combination of the muriatic acid with soda. If sulphuric or vitriolic acid be added, the soda will quit its acid to unite by stronger affinity with the acid last added, with which it will form a new salt, called sulphate of soda or Glauber's salt, while the muriatic acid being disengaged, flies off in an elastic form.

E When two compounds, consisting each of two principles, are presented to each other, and the combinations change the order of their principles, two decompositions, and two new combinations, are said to be produced by double affinity.

F Muriate of ammonia is composed of muriatic acid, combined with ammonia or volatile alkali. If muriate ammonia in powder be mixed with slaked lime, the muriatic acid unites with the lime, and the water of the lime joins with the volatile alkali, which rises immediately in penetrating fumes. This mixture being hastily put into a retort, the water and volatile alkali

come

come over together, by the assistance of a gentle heat, in the form of a pungent fluid, called liquid ammonia, or caustic volatile alkali. In this process it is not simply the attraction of the muriatic acid to the quicklime, nor the attraction of the water to the alkali that occasions the double change of combination, but it is the united force of both attractions: for if dry hot quicklime, that is to say, quicklime containing no water, be made use of, the muriate of ammonia is not decomposed, the simple attraction of the muriatic acid to the quicklime not being sufficient to overcome the attraction of its component principles.

Fluids in general dissolve a greater quantity of any substance when the temperature is higher; but this is not universally true. The cause of the general fact seems to be, that the fluidity of the matter in solution may be better maintained (128, u) at a higher temperature; that in partial solutions, where all the principles are not taken up, the heat, by volatilizing some principles, may render the solution of the residue more easy: and the reason why in some cases less is taken up by a fluid at a higher than at a lower temperature is, probably, that the general effect of heat being to oppose (113, x) the attractions between bodies may operate more strongly than the other causes here taken notice of. But it is probable that none of the cases wherein this effect seems to take place are of a simple nature.

## CHAP. IV.

### OF THE FIRST COMPONENT PRINCIPLES OF BODIES, OR SUCH AS ARE THE MOST SIMPLE.

By the term of ſimple bodies, chemiſts mean ſuch ſubſtances as cannot be ſeparated into others of a more ſimple nature, or reproduced by artificial means. Some of theſe ſubſtances can only be exhibited to our view in their ſimple ſtate; others, on the contrary, have not yet been ſucceſsfully exhibited uninſulated. Their exiſtence can nevertheleſs be inferred from the analogy of certain general and well-eſtabliſhed facts; they may be arranged in the following order:

1. *Simple ſubſtances, without appreciable weight, and of doubtful exiſtence as ſuch.*

| | |
|---|---|
| Caloric. | Light. |
| Electricity. | Galvaniſm. |

2. *Ponderable Simple Subſtances.*

A COMBUSTIBLE BODIES.

| | |
|---|---|
| Sulphur. | Diamond. |
| Phoſphorus. | |

B METALS.

| | | |
|---|---|---|
| Platina | Mercury | Titanium |
| Gold | Tellurium | Colombium |
| Silver | Antimony | Chrome |
| Copper | Biſmuth | Molybdena |
| Iron | Manganeſe | Tungſten |
| Lead | Nickel | Arſenic |
| Tin | Cobalt | Tantalium. |
| Zinc | Uranium | |

*Incombuſtible*

### *Incombuſtible Bodies.*

EARTHS. C

| | |
|---|---|
| Silex | Glucine |
| Alumine | Zircon |
| Barytes | Yttria |
| Strontia | Magneſia. |
| Lime | |

ALCALIES. D

| | |
|---|---|
| Potaſh | Soda. |

2. *Simple Subſtances not yet producible by art.*

| | |
|---|---|
| Oxigen | Muriatic radical |
| Nitrogen | Fluoric radical |
| Hidrogen | Boracic radical. |

Such are the bodies which chemiſtry conſiders as ſimple. It does not however follow, that they are abſolutely ſo. They are only ſimple according to the preſent ſtate of our knowledge. It is very poſſible that as the ſcience advances towards perfection, many of them will be found compound, and a new ſet of ſimple bodies will preſent itſelf, of which we are at preſent ignorant.

## CHAP. V.

### THEORY OF COMBUSTION, AND COMBUSTIBLE BODIES.

1 WHEN an *incombustible* body, a stone, for instance, is heated, it undergoes no change except an augmentation of bulk and increase of temperature, and when left to itself it soon acquires its former state. But when a *combustible* body is heated to a certain degree in the open air, it begins to become on a sudden intensely hot, and at last emits a copious stream of heat and light to the surrounding bodies. During this emission of heat and light, the body gradually wastes away. It either disappears entirely, or its physical properties are totally destroyed. The principal change it suffers is, that of being no longer combustible. If either of these phenomena, namely the emission of heat and light, and the waste of substance, be wanting, we do not say that the body is undergoing combustion, or that it is burning. Combustion is, therefore, always attended by the disengagement of heat and light.

2 The elder chemists universally supposed, that the heat and light emitted during combustion proceeded from the combustible body. The burning body appeared luminous and felt hot, and no other agent was supposed to be concerned: the conclusion, that light and heat were evolved from the burning body, was therefore unavoidable.

But

But when the nature of the atmosphere was ascertained, and when it became evident that part of the air was absorbed during combustion; the former conclusion fell to the ground. For when two bodies exert a mutual action on each other, it becomes equally probable that the products may be derived from either of them; consequently the light and heat evolved might proceed either from the one or the other. Whether they proceed from the atmosphere, or from the combustible body, they must be separated at the part where the combination takes place, that is, upon the surface of the burning body itself, and consequently it appeared luminous and heated, while the air being invisible escaped observation.

When the laws of heat became known, at least when it was proved that bodies in the aeriform state, contain at the same temperature, and in equal quantities, either of mass or bulk, unequal quantities of heat, the conclusion became probable, that the caloric evolved in combustion proceeded rather from the oxigen gas of the atmosphere, than from the combustible body, since the former contains a much larger quantity than the latter. The caloric evolved was therefore deduced from the *condensation* of the oxigen gas in the new combustion into which it entered. Though approaching to truth, this explanation is perhaps not strictly true. It is not merely from the oxigen gas being condensed, that the caloric is evolved, because in many cases of combustion the product still exists in a gareous state, and in others the quantity of caloric bears no proportion to the degree of condensation. Philosophers ascribe

cribe this to a change of capacity, for in different bodies the difference in the proportion of the capacities before and after combustion is by no means the same; and hence the difference in the quantities of caloric extricated in various cases of combustion. This being premised, it remains to explain the origin of the light emitted during combustion; for although it might be taken for granted, that the caloric is evolved from the oxigen gas, we cannot infer that the light has the
I same origin. It is very probable that light is a constituent part of inflammable bodies, for it is frequently evolved in combinations when the oxigen is merely transferred from one inflammable substance to another. In those cases it must proceed from the combustible body. It seems therefore probable that the light is derived from the inflammable substance, and that the oxigen combining with the bases of these substances, disengages the light. It is *possible* that part of it may also be derived from the oxigen gas, but it is evidently unnecessary to *suppose so*. Such is the theory of combustion modified by modern chemists.

K The simple bodies, which are capable of undergoing combustion, have been enumerated before; we shall now exhibit their properties.

L Diamond. The diamond is a combustible substance which, on account of its great commercial value, has not been submitted to many experiments; it is found in various parts of the Mogul empire, and also in the East Indian Islands, and the Brasils. It is usually of an octohedral form, though not unfrequently in round masses. The consent of mankind has stamped

a pro-

a prodigious value on the diamond; its great lustre, which seems to have been the property that originally attracted their notice, is owing to two causes. The first is, that being the hardest of all bodies, it takes and preserves a most exquisite polish, and the other is, that its refractive power is so much greater than that of any other medium, as to occasion all the light to be reflected (1, 270. A) which falls on any of its hinder surfaces at a greater angle of incidence than $24\frac{1}{4}$ degrees. Now at a less angle of incidence in glass on the internal surface than 41 degrees, the light will be transmitted; consequently if an artificial gem and a real diamond be compared, the light falling on each alike situated will be thrown back with its full glare from a diamond not only in all the cases wherein glass will reflect it, but likewise at all the angles between $41^\circ$ and $24\frac{1}{4}^\circ$, while the glass suffering it to pass through will appear lifeless and dull. It is no wonder, therefore, that the effect of the diamond is so much greater.

It is not acted upon by any chemical agent, except oxigen at a very intense heat. In that case it burns like any other combustible body. The product of this combustion is carbonic acid gas, 100 parts of which consist of 17,88 carbon, and 82,12 oxigen. It converts iron into steel; hence it is considered as pure or crystalised carbon.

Carbon is capable of uniting with different portions of oxigen; charcoal, gaseous oxid of carbon, and carbonic acid, are compounds containing oxigen in different proportions.

O Charcoal forms the ſkeleton of plants. It is alſo contained in animal and mineral ſubſtances. If a piece of wood be put into a crucible and covered with ſand to exclude the air, and the crucible be kept red hot for ſome time, the wood is converted into a black ſhining ſonorous ſubſtance, called charcoal. It moſt commonly retains the form of the vegetable which affords it. It is carbon in the firſt degree of oxigination. It is ſolid at all known temperatures. It burns with vivid light in oxigen gas.

P Gazeous oxid of carbon is obtained by the action of ignited charcoal on certain metallic oxids, particularly zinc and iron. It is carbon in the ſecond degree of oxigination. It always exiſts in the gazeous ſtate. Carbonic acid gas is produced when diamond or charcoal is burned in oxigen gas; or by the effuſion of an acid upon a natural or artificial carbonate. It is carbon perfectly oxidated. It exiſts in the ſtate of a permanent gas.

Q The combination of carbon with iron forms ſteel.

R Sulphur, or brimſtone, is an inflammable ſubſtance of a light yellow colour, either tranſparent or opake, brittle, odorant; it enters into combination with oils, alkalis, earths, and metals, at a temperature not much greater than that of boiling water; it evaporates in the open air, emitting a flame which by day has the appearance of a white fume, but in the dark is luminous, though its heat is ſo ſmall that it may be ſuffered to play againſt the palm of the hand without much inconvenience. At a higher temperature it

burns

burns with a vivid blue flame, and is rapidly converted into ſulphuric acid gas. This gas unites with water if preſent, and forms the volatile vitriolic or ſulphureous acid.

Sulphur ſublimes without alteration if heated in a s
cloſe veſſel. It is capable of combining with different quantities of oxigen, conſtituting oxid of ſulphur, ſulphureous and ſulphuric acid. Oxid of ſulphur is formed during the ſlow fuſion of ſulphur; it is a tenacious maſs of a brown colour while hot, but it ſolidifies when ſuffered to cool. It has a peculiar auſtere taſte. It has been little examined. Sulphureous acid is produced during the ſlow combuſtion of ſulphur, as juſt noticed. Sulphuric acid is produced during the rapid combuſtion of ſulphur, as will be noticed hereafter.

The primary combination of ſulphur with earths T
or alcalies conſtitutes the binary compounds, called alcaline, or earthy ſulphurets; moſt of them have a brown or liver colour; when perfectly dry they are void of odour, but when moiſtened they become inſtantly converted into hydrogurated ſulphurets; they then exhale a peculiar odour reſembling rotten eggs. They may be obtained by mere fuſion.

The combinations of ſulphur with metals form U
ſubſtances, called metallic ſulphurets: moſt of them have a metallic aſpect, they alſo decompoſe water, become odorant, and are converted into hydrogurated ſulphurets by the addition of water.

Sulphur combined with phoſphorus forms ſulphu- X
retted phoſphorus.

Sulphur

y Sulphur combined with hydrogen constitutes sulphurated hydrogen gas; which see.

z Sulphur is found pure principally near volcanoes and in combination with metals; it exists also in animal and vegetable substances.

A Phosphorus is a yellow or white transparent substance of the consistence of wax, but brittle in the cold. It exhibits a crystalline appearance when broken. It is luminous at common temperatures. It melts at 105° and takes fire at 160°. It is soluble in expressed and essential oils, in ether and alcohol. It combines with alcalies, earths, sulphur, and with metals. It is soluble in hydrogen gas. It is capable of combining with two different portions of oxigen, forming phosphorus and phosphoric acids.

B Phosphorus is never found pure in nature, but always in combination with oxigen, constituting phosphoric acid, and then united to lime or other bodies. It is obtained from bones of animals, in the following manner: To 3 gallons of water add gradually 1 lb. 6 oz. of sulphuric acid of commerce, heat the mixture in a leaden or glass vessel, and add gradually 3 lb. of bones, burnt to whiteness and finely pulverised, and digest the mixture by heat for 2 or 3 hours. Strain the whole, and evaporate the strained fluid to about 4 lb. Separate the sulphate of lime if any is precipitated during this process. Evaporate the fluid to a syrupous consistence, and then transfer it into a crucible capable of holding at least six times the quantity; fuse it till it flows quietly, and liquid like water; add to it gradually 3 oz. of charcoal powder,

stir

ſtir the mixture intimately together; transfer the mixture into a ſtone retort, the neck of which is immerſed in water, and diſtil with a heat gradually increaſed to whiteneſs. The phoſphorus will paſs and be collected in the water.

The primary compounds of phoſphorus are, oxid of phoſphorus, phoſphorus acid, phoſphoric acid, phoſphurated ſulphur, alkaline, earthy, and metallic phoſphurets, and phoſphurated hydrogen gas. C

Oxid of phoſphorus is formed by expoſing phoſphorus to the joint action of water and light; it appears in the form of an orange cruſt on the phoſphorus. D

Phoſphorets and phoſphoric acid are produced, the firſt by ſlow, the latter by a rapid oxigenation of phoſphorus. See phoſphorus and phoſphoric acid. E

Phoſphuret of ſulphur is produced by fuſing phoſphorus and ſulphur under warm water. It is a highly inflammable compound, capable of decompoſing atmoſpheric air and nitrous acid at common temperatures. F

Alkaline and earthy phoſphurets are obtained by heating phoſphorus in contact with theſe bodies. The moſt known phoſphuret of this kind is phoſphuret of lime, which may be produced in the following manner: Take a Wedgwood tube, made of Wedgwood ware, cloſed at one extremity, put into it 1 part of phoſphorus, and upon it put 4 of lime, reduced to ſmall pieces (not in powder), heat that part of the tube which contains the lime red-hot; this being done apply heat to the cloſed extreme of the tube where the G

the phoſphorus is ſituated, and ſublime the phoſphorus over the lime; the compound thus obtained is phoſphuret of lime. It has the property of decompoſing water. If a ſmall piece of it be dropt into this fluid, phoſphorated hydrogen gas will be diſengaged, which takes fire at the ſurface of the fluid. Phoſphuret of barytes, and phoſphuret of ſtrontia may be formed in a ſimilar manner.

H Metallic phoſphurets are beſt produced, by mixing the filings of the reſpective metals with glacial phoſphoric acid and charcoal, and expoſing the mixture to a red heat.

I Phoſphorated hydrogen gas will be noticed under the articles treating of gaſes.

## CHAP. VI.

### METALS IN GENERAL.

F THE internal parts of the earth, as far as the excavations made by natural cauſes, or by the induſtry of man, have given ſcope for obſervation, exhibit ſtriking marks of the immenſe changes that have been produced by the chemical action of bodies on each other, during a courſe of ages far preceding all
G human record. It ſeems probable that the loftieſt mountains, which run in chains through the great continents, and are compoſed chiefly of granite, had their exiſtence as ſuch previous to that of the animals
H or vegetables on the earth. The ſame remark applies likewiſe

likewiſe to mountains of limeſtone, or marble of a
granular texture, and is founded on the conſideration,
that the remains of thoſe organized ſubſtances are
never found in them. Other mountains, for the con- I
trary reaſon, are evidently of poſterior formation.
Such as have their materials arranged in ſtrata or beds,
ſeem to have been formed by ſubſidence and cryſtal-
lization in water. The planes thus formed, appear,
from a variety of ſigns, to have been disjoined, broken,
and thrown up into heaps by earthquakes, or ſimi-
lar convulſions of nature. Volcanos, or the eruption K
of ſubterraneous fires, have alſo contributed greatly to
change the internal conſtruction and external appear-
ance of the globe we inhabit. There is no country or L
climate where veſtiges of theſe awful phenomena are
not plentifully to be met with. Volcanic hills are
often pyramidical, with a plain, or hollow cavity at
top, and have one or more ridges proceeding from
thence as a center. Strata of lava, and other vol-
canic products, abound in the vicinity, moſtly be-
neath the ſurface, and are regularly diſpoſed ſo as to
point out the ſource from which they formerly iſ-
ſued. Metallic bodies are moſtly found in the ſtra- M
tified mountains. The beds of theſe mountains
being thrown up into an inclined poſition, appear
to have been worn down by the long continued ac-
tion of the atmoſpheric changes; ſo that ſtrata,
which in lower grounds are too deep for the mi-
ners to arrive at, are here rendered acceſſible.

Such metallic combinations as are found in nature N
are called ores. The metal is ſaid to be mineralized

by the ſubſtance that is combined with it. It muſt, however, be obſerved, as an exception, that native
O *metallic ſalts are not called ores?* The chief mineralizers are ſulphur, oxigen, and arſenic. Metals are alſo found native or uncombined; but ſparingly.

P There are entire mountains which conſiſt of iron ore: other ores form but an inconſiderable part of the mountain in which they are found. Some ores run parallel to the ſtony ſtrata, though very far from having that regularity of thickneſs thoſe ſtrata poſſeſs; others croſs the ſtrata in all directions. The laſt are called veins.

Q The ſtones wherein the ore is imbedded are called its matrix. Theſe are not peculiarly appropriated to any metal, but ſome ſtones more frequently accompany metals than others.

R The art of extracting metals from ores in the ſmall way is called aſſaying or eſſaying. The term is alſo applied to the ſeparation of gold or ſilver from other metals, and procuring them alone. Ores may be aſſayed either by the dry or humid method. In the dry way the proceſs is conducted nearly in the ſame method as when the metals are extracted in the large furnaces, and generally ſpeaking, diſcovers little more than the quantity of the metal contained in the ore. In the moiſt way, by ſkilful management, the quality and quantity of all the ingredients become known *.

* The practical rules for conducting the analyſis of ores, and minerals in general, may be ſeen in "Accum's Practical Eſſay on the Analyſis of Ores, Earths, Stones, &c."

The proceſs by fire for obtaining metals from their ores in large quantities for commercial purpoſes, is called ſmelting. S

The operations for ſeparating metals from ores are trituration, and waſhing in a ſtream of water, by which the lighter parts are carried off, while the heavier ſubſide. This is of ſervice when the metalliferous parts are conſiderably heavier than the reſt. Roaſting, by which ſulphur, water, arſenic, or other volatile and uſeleſs ſubſtances are diſſipated. Fuſion or ſmelting with ſuch a mixture of earths, or other matters as may facilitate the ſame, by which the ſuperfluous part of the ore is ſcorified, or melted into a ſlag or glaſs, ſufficiently thin to allow the metalline particles to ſubſide to the bottom of the furnace in a reguline ſtate. T
In aſſays, combuſtible or coaly matters are uſed for fluxing the maſs, that the metal may be reduced by depriving it of the minerallizing ſubſtance with which it may be combined; but in large works the fuel generally anſwers that purpoſe. U

It is obvious, that the trituration, waſhing and roaſting, are not in all caſes required; that in ſome caſes the roaſting muſt precede the trituration; and that the additions in the ſmelting require an attention to the ſuppoſed or known contents of the ore required to be fuſed. V
The previous examination of ores by the blow-pipe, (134, G) and more eſpecially the humid analyſis, are of great ſervice, by indicating the proper additions to be made in ſmelting. W

In the humid way the ore is finely powdered, and diſſolved in ſuch a menſtruum as is adapted to take X

up

up either the whole or ſome of the parts conjectured, or by blow-pipe experiments known, to enter into its compoſition. The undiſſolved reſidue, if any, is ſubjected to trials by other menſtruums. The parts in ſolution may be ſeparated by the addition of precipitating matters, or by various other proceſſes. The properties and weight of the obtained products indicate both the quality and quantity of each ſubſtance contained in the ore. This method of aſſaying is incomparably more exact than the other, but it requires an extenſive application of the principles of the moſt enlightened chemiſtry *.

Y Metallic ſubſtances in their reguline ſtate have a peculiar brilliancy and opacity (170, z.) Properties, undoubtedly owing to their great denſity, and their combuſtible nature. For the refractive power which bodies exert on light is found to be nearly as their denſities (1.262, A) excepting inflammable ſubſtances, and in theſe it is in a higher proportion. And, becauſe the refraction and reflection of light ariſe from the ſame cauſe (1. 308, E) ſuch bodies as refract moſt will alſo reflect the light moſt ſtrongly. Opacity is a conſequence of the reflection of light. White metals are very opake. Gold leaf, which is about † the $\frac{1}{282000}$ part of an inch thick, tranſmits light of a

* See Bergman's Opuſcula, and Kirwan's Mineralogy.

† This is the thickneſs deduced from the weight and ſurface of a book of gold, when the metal is ſo fine as to have but three grains of alloy in the ounce, and the workman extraordinarily ſkilful. Finer gold cannot be wrought in this way, becauſe it is too ſoft to expand over the irregularities of the gold-beater's ſkins.

beautiful

beautiful green; but silver-leaf, which is about the $\frac{1}{160000}$ of an inch thick, is opake. Other metals have not been so much extended, and whether any of them are susceptible of it is not known.

Melted metals, like all other fluids, assume a symmetrical form in cooling (152, x). The chrystals are larger the slower the transition from the fluid to the solid state; and the specific gravities of some, and, perhaps, all metals, are greatly affected in the same specimen (17, w) from this circumstance. Several metals are capable of having their crystals separated by agitation or pounding, just at the time of congelation; and have then a powdery or granular form. These, if struck with a hammer immediately after congelation, are broken, and exhibit the regular arrangement of their internal parts. Lead and bismuth afford remarkable instances of this. Z

Most metals will mix in all proportions with each other, though perhaps not uniformly, and may be afterwards separated by processes founded on the consideration of their various fusibility, solubility, or disposition to become oxidated. A

The specific gravities of these metallic compounds are scarcely ever such as would be mathematically deduced from the specific gravities of the metals made use of, on the supposition of their junction by simple contact. B

The fusibility of these compounds is likewise such in several instances as would not be expected from the fusibility of the ingredients. C

 The

D The portion of baser or less valuable metal that is mixed with gold or silver, is called alloy.

E Some metals are burnt or oxidated by heat with access of air: during this process they combine with the oxigen of the atmosphere. Molybdena, arsenic, tungsten, chrome, and columbium, are capable of uniting with a large portion of oxigen, and then become acid.

F Metallic oxids are reduced to the metallic state by strong heat, in contact with combustible matter (152, W. 167, Q). The black flux is very serviceable for this purpose; for, at the same time that its combustible part reduces the metal, its thin fusion favours its subsidence.

G Oxids of metal are heavier absolutely, but not specifically, than the metal they were produced from.

H Metals are soluble in acids, but not in their metallic state. Such acids as cannot oxidate a metal exposed to their action do not dissolve it, though they will take up the oxid.

I When a metal is dissolved nearly to saturation in an acid, it will be precipitated in its metallic form by the addition of another metal, provided the attraction of the dissolved oxid for oxigen of the metal last added, together with its attraction for the acid be less powerful than the same attractions on the part of the metal which is added.

K Sulphur unites with all metals, and the alkaline sulphurets combine with them all.

L The ductile metals, gold, platina, silver, copper, iron,

iron, lead, tin, and mercury, may all be oxidated by mere heat. Some require the moſt intenſe heat, others are oxidated at lower temperatures. Platina, gold, and ſilver, can hitherto be only oxidated by the galvanic and electric ſparks.

Gold is a yellow metal of much greater ſpecific gravity than any other, except platina (17, w); directly ſoluble in nitro-muriatic acid (192, v), and the oxigenated muriatic acid, and precipitable from theſe in its metallic form, by the ſolution of green ſulphate of iron, and ſulphuric ether. It has all the metallic characters (170, z) in the moſt perfect degree. When in fuſion, it has a ſea-green colour, which is alſo the colour of gold-leaf by tranſmitted light. r

Gold is moſtly, if not always, found in its metallic ſtate. Some ſands afford gold by ſimple waſhing, the heavy metallic particles ſubſiding ſooneſt. But when embodied in earths, or ſtones, theſe are pulverized and triturated with one tenth of their weight of mercury, together with water. The mercury, after a certain time, unites with the gold, and may be ſeparated by diſtillation. Or otherwiſe by heating the ſand red-hot, and quenching in water ſeveral times, for the purpoſe of cracking and dividing it, and then melting the whole into glaſs with twice its weight of vitreous oxid of lead, or litharge. Charcoal being added, revives the litharge into lead, which ſubſides to the bottom, carrying the gold with it. If the lead, thus ſeparated from the ſand, be again converted into litharge by oxidation, the gold will remain ſeparate at the bottom of the teſt (130, x). q

R The last operation, called testing, or cupellation when performed in the small way, is one of the best methods of separating gold from the more easily oxidable metals. The mass of metals to be cupelled is put, together with lead, into a small shallow crucible of burned bones, called a cupel, and fused with a considerable heat, with access of air. The lead continually oxidates, and combines all the other metals with it. No litharge is produced in the small way, because it is imbibed by the porous cupel. During the cupellation, the scoriæ, running down on all sides from the metallic mass, produce an appearance called circulation, by which the operator judges that the process is going on well. When the metal is nearly pure, certain rainbow colours flash across the surface, which soon after appears very brilliant and clean. This is called the brightening, and shews that the cupellation is ended.

S If the cupelled mass contain more gold than silver, the gold may be dissolved by nitro-muriatic acid, and the silver will remain in the form of a white powder, or muriate of silver. If the silver prevail, pure nitric acid wiil dissolve it, and leave the gold. It is found most advantageous to add pure silver, if required, to make the proportion of this metal to the gold as three to one. For in this case the quantity of silver is not so small as to be protected by the gold from the action of the acid, nor the gold so small as to fall into powder, when deserted by the silver. These processes are called parting.

T If platina be supposed to be mixed with the gold, both

both may be dissolved in nitro-muriatic acid, and the gold will be precipitated alone on the addition of green sulphate of iron. The sulphate of iron thus used becomes more oxidated than before, by robbing the gold of all its oxigen, which, therefore, reappears in its metallic state.

The precipitate of gold from its solvent by ammonia (192, v), has a power of detonating, with a moderate heat, the gold being at the same time revived. The force of this explosion is not so great as that of gunpowder, if a judgment may be formed by burning it in a closed metallic vessel; but is much greater, if attention be paid to the prodigious noise it makes, and the laceration of the metallic plate it is burned upon. These contrary conclusions may be reconciled, either by supposing the force of aurum fulminans less than that of gunpowder, but that its velocity of expansion is greater at the beginning; or otherwise, by supposing its force to be greater, but that, when inclosed and in contact with red-hot metal, the powder is decomposed in another way without explosion. Experiment must, however, determine. From various experiments upon this dangerous compound, it is ascertained that it is an ammoniacal oxi-muriate of gold.

The explosion depends on the muriatic acid seizing the oxigen, and thus reducing the gold to its metallic state, while the simple muriatic acid in return becomes converted into oxigenated muriatic acid. This acid meeting with the nascent ammonia detonates, in which case part of the oxigen of the oxigenated muriatic acid joins to the hydrogen of the ammonia, and

produces water, the nitrogen of the latter being ſet free; hence the products of the detonation of this compound ſeem to be metallic gold, muriatic acid, water and nitrogen.

v Tin, either diſſolved in nitro-muriatic acid, or in ſubſtance, added to a ſolution of gold, precipitates the gold in the form of a beautiful purple powder, called the purple powder of Caſſius, which is of uſe in enamels, as it gives a fine tinge to glaſs. The preparation of this powder, and the production of a clear ruby coloured glaſs, require peculiar management.

w Volatile oils, charcoal, and more particularly ether, take gold from its ſolvent, but no other metal. If the ether be left to evaporate, by imperfectly cloſing the phial, the gold falls in its metallic form, no longer ſoluble by the acid beneath. Theſe methods purify gold from all admixtures.

x Alkaline ſulphurets combine with gold in the dry way into a maſs, diſſolvable in water.

y The imaginary value of gold probably originated in its property of bearing the action of the air, and all other liquids commonly met with, without tarniſhing or ruſting; to which value, no doubt, its great and almoſt inimitable ſpecific gravity has contributed.

The gold coins of Britain conſiſt of eleven parts gold to one of copper. The alloy is required to give the neceſſary hardneſs.

z Platina has been found hitherto only in a metallic ſtate in the gold-mines in Peru. It comes over in the form of grains, intermixed with ferruginous ſand, plumbage, and quartz. The grains that remain,

main, after the moſt magnetical and other particles have been ſeparated, are of a whiter colour than iron. Theſe contain a conſiderable portion of iron, and have a ſpecific gravity of 16 or 18. To purify it, it muſt be repeatedly boiled in muriatic acid, then waſhed, and diſſolved in nitro-muriatic acid; to this the pruſſiate of potaſh is to be added till it ceaſes to precipitate any iron; the clear ſolution being decanted off, the addition of muriate of ammonia will throw down the platina, which may be fuſed in the moſt violent heat of a furnace. No other metal is precipitable by this ſalt.

Platina thus purified, is by much the heavieſt body B
in nature (17, w). It is very malleable, though conſiderably harder than either gold or ſilver. Its colour is not diſtinguiſhable from ſilver on the touchſtone. When in the higheſt degree of purity it is not magnetical; but when its ſpecific gravity is as low as 21.36, it ſtill contains iron ſufficient to render it ſuſceptible of the magnetic touch, and obedient to a ſtrong magnet *. It is ſoluble only in nitro-muriatic acid, and is not acted on by ſulphur. Mercury does not combine with it in a direct manner. It withſtands cupellation.

Platina unites with moſt of the other metals, and C
with phoſphorus. It is oxidated by the galvanic ſpark.

Silver is the whiteſt of all metals, ſoluble in dilute D
nitric acid, and in a mixture of ſulphuric and nitric

* See the ſection on Magnetiſm.

acid by the aſſiſtance of heat. It is precipitable from either of the firſt mentioned acids by the addition of muriatic acid, which combines with its oxid, and forms an inſoluble compound, called muriate of ſilver. Its malleability, compared with that of gold (231, Y), is nearly in proportion to its ſpecific gravity.

E Native ſilver is found in a great variety of forms, and imbedded in various earths, generally alloyed with other metals. Some of the maſſes have been found of the weight of ſixty pounds. The greateſt quantity of this metal comes from Peru.

F The ores of ſilver are very numerous. Sulphur, arſenic, muriatic acid, iron, copper, antimony, are the ſubſtances that ſeverally or collectively, in greater or leſs proportions enter into their compoſition.

G The ſolution of ſilver, in the nitric acid, affords nitrate of ſilver, in ſmall cryſtals. This ſalt detonates when heated with combuſtible matters, but fuſes in a moderate heat, without addition into a dark coloured maſs, uſed by ſurgeons as a cauſtic, under the name of lapis infernalis.

H Muriatic acid, or common ſalt, being added to a ſolution of ſilver, the ſilver falls down in combination with more than its weight of the muriatic acid. This compound melts in the fire, at a low red heat, and if caſt into thin plates, is ſemi-tranſparent, and ſomewhat flexible like horn; whence its name luna cornea. If carefully prepared, it proves clear, and is ſuppoſed to have given riſe to the notion of malleable glaſs. A greater heat does not expel the acid, but the whole concrete either riſes in fumes, or paſſes

through

through the pores of the veſſel. As the muriatic acid throws down only ſilver, lead, and mercury, and the latter two of theſe are not preſent in ſilver that has paſſed the cupel (236, R) though a ſmall quantity of copper may elude the ſcorification in that proceſs, the ſilver which may be revived from muriate of ſilver is purer than can be eaſily obtained by any other proceſs. It is reducible by trituration with double its I
own weight of potaſh or ſoda; and afterwards melting the whole in a crucible, whoſe bottom is covered with ſoda well preſſed.

The property of ſilver of forming a ſcarcely ſolu- K
ble compound, with muriatic acid, affords a good teſt for detecting the preſence of ſmall quantities of that acid, containing it in any liquid. For by dropping the ſolution of ſilver in nitric acid into ſuch liquids, a cloud, of a curd-like appearance, will be immediately formed by the combination of the oxid of ſilver with the muriatic acid, if preſent. This property L
alſo affords a method of purifying the nitric acid (184, O) from the muriatic acid which it generally contains.

Silver is not corroded by the action of the atmo- M
ſphere; but is very apt to tarniſh and grow black by expoſure to ſulphureous vapours.

Sulphur, and alſo alkaline of ſulphurets combine N
with ſilver in the dry, and in the humid way.

The fulminating compound of ammonia with oxid of ſilver, exhibits one of the moſt aſtoniſhing inſtances of chemical detonation hitherto obſerved. Its pro- O
perties

perties were discovered by Berthollet *. Pure silver is dissolved in pale nitric acid, and the oxid precipitated by lime-water. After decantation of the fluid, the precipitate is exposed to the air for three days to dry, in which the inventor thinks the presence of light is requisite. This dried oxid being agitated or stirred in a solution of liquid ammonia, assumes the form of a black powder which, when separated by decantation, and dried in the air, is the fulminating silver. The alkaline fluid likewise contains a portion of silver in solution, which may be separated by evaporation, and cooling so far as to afford crystals, which also possess the detonating property.

Gunpowder and fulminating gold are not to be compared with this new product, for the first requires ignition, and the latter a perceptible degree of heat to produce detonation. But the slightest agitation or contact is sufficient to cause the silver to explode. When once obtained, it can no more be touched. Even the falling of a drop of water upon it produces the explosion. No attempts can therefore be made to enclose it in a vessel. None but metallic vessels can be used in the latter part of the process. The safety of the operator will be endangered if any quantity exceeding a grain of silver be used, and even in this case it is proper that his face should be defended by a mask, with apertures for the eyes covered with strong glass.

* Journal de Phisique, June 1788.

The

The theory of this detonation is the same as that of fulminating gold.

It is a valuable discovery of Mr. Kier*, that a mixture of strong sulphuric acid with the nitrous acid or nitrate of potash is a powerful solvent of silver, though it scarcely acts upon the metals. This is of considerable importance in the Birmingham manufactures, where the silver in the cuttings of plated copper is required to be separated from this last metal. For this purpose the pieces of metal are put into a glazed earthen pan, and a composition of eight or ten pounds of sulphuric acid, with one pound of nitrate of potash, is poured upon them, stirred about, and the action of the fluid assisted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly saturated, the silver is to be precipitated by common salt, which may be easily afterwards reduced, or otherwise the silver may be precipitated in its metallic state, by adding to the solution a few of the pieces of copper and a sufficient quantity of water, which enables the liquor to act on the copper.

Silver is changed into a grey oxid by long and violent heat, the galvanic spark instantly causes it to burn with a greenish white light.

It wastes but slightly with the acidifiable metals and iron; but combines readily with most of the rest of the metals.

Most of its oxids are blackened, or partly reduced by light, heat, and hidrogen gas. They are soluble in liquid ammonia.

* Phil. Transf. 1780, p. 367.

Pure

o Pure silver, like pure gold, is too soft to be used for ordinary purposes without alloy. In the British coinage fifteen parts of silver are alloyed with one of copper.

Q Mercury or quicksilver is a metal of a bluish white colour, very little susceptible of tarnishing by exposure to the air. It is always fluid at our temperatures, but becomes solid at 40 F. Its volatility is such that it is driven off by actual ebullition, at a temperature (127, R) which the greater part of the other metals sustain without melting. In its solid state it is malleable. Its specific gravity (17, W) is 3,563. By a heat, nearly sufficient to cause it to rise quickly in the vaporous form, it is oxidated provided the access of atmospherical or oxigen gas be allowed. This oxid improperly called percipitate per se, is of a red colour, and resumes its metallic form by mere increase of heat, at the same time that it gives out oxigen gas.

Native mercury is frequently found, but perhaps never free from metallic alloy. It is also found mineralized, in the form of a red oxid, or combined with the sulphuric or marine acids, or with sulphur. This last is called native cinnabar. It is of various colours, from a yellowish to a deep red, and is very ponderous. In close vessels it sublimes without any other alteration than being deprived of its impurities; in open vessels,
v with sufficient heat, it is decomposed. The mercury is obtained from it by distillation, with the addition of some substance that will combine with, and detain the sulphur; for which purpose iron or lime is commonly made use of. But if calcareous earth be mixed with

or

or abound in the ore, no other addition is requiſite. v
The pigment called vermilion, is an artificial cinnabar, produced by combining mercury with ſulphur by trituration and ſublimation. One hundred parts of cinnabar contain eighty-five of mercury, and fifteen of ſulphur. It was until lately ſuppoſed to conſiſt of red oxid of mercury and ſulphur, but Prouſt * has aſcertained that it contains metallic mercury and ſulphur in the proportions here ſtated.

Mercury is judged to be pure when it is perfectly w
fluid, and runs in neat globules, without any pellicle on its ſurface, or without ſoiling a funnel of clean white paper, through which it may be poured by a very ſmall aperture at bottom. If it leaves nothing x
behind after evaporation, its purity may be ſtill more depended on. For purpoſes where the utmoſt purity is required, the mercury may be triturated with pulverized ſulphur, till it diſappears. by uniting with that ſubſtance in the form of a black powder, with this may be mixed twice the quantity of quicklime or filings of iron, and the whole being ſubmitted to diſtillation, the mercury will riſe, and paſs into the receiver. Duſt, y
and other ſuperficial impurities, are removed by preſſing mercury through a leathern bag.

The concentrated ſulphuric acid, by boiling combines with mercury into a white maſs, which by the effuſion of a ſufficient quantity of hot water, becomes of a citron colour. It is ſcarcely at all ſoluble in water, and is known in medicine by the

* Journ. de Phyſ. III. 92.

the

the name of turbith mineral, or yellow ſub-oxid of mercury.

z Nitric acid diſſolves mercury very readily, and affords, by cryſtallization, a ſalt called nitrate of mercury. If this ſalt, which is white, be expoſed to heat, it becomes yellow, then orange coloured, and, laſtly, red, in which ſtate it is found not to differ from red oxid of mercury (243, R. 182, O).

Mr. Howard has diſcovered that mercury and moſt of its oxids, when treated with nitric acid and alcohol are converted into fulminating compound; his method of preparing fulminating mercury is as follows:

Diſſolve 100 grains of mercury with heat in a meaſured ounce of nitric acid; pour this ſolution *cold* upon two meaſured ounces of alcohol; apply a very moderate heat till an effervеſcence is excited. Collect the precipitate which is formed after the effervеſcence has ceaſed, waſh it immediately, and ſuffer it to dry at a heat not exceeding 212°. This powder when ſtruck on an anvil explodes with a loud report. The ſhock of an electric, or galvanic battery ſent through it produces a ſimilar effect. From a ſeries of well conducted experiments Mr. Howard concludes that it conſiſts of oxid of mercury, oxalic acid, and nitrous etherized gas *.

A Sulphuric acid, added to a ſolution of mercury in nitric acid, ſeizes the metallic oxid, and falls to the

* Phil. Tranſ. 1800. p. 214.

bottom;

bottom; forming the ſame combination as would have been produced by the direct ſolution of mercury in the ſulphuric acid (245, Y). The affuſion of boiling water converts it into yellow ſub-oxid of mercury.

Muriatic acid does not diſſolve mercury, though it B
readily unites with its oxids. Thus, when mercury is oxidated by nitric acid, in which it is diſſolved, the muriatic acid being added, immediately ſeizes the oxid, and forms muriate of mercury, a ſalt of difficult ſolubility, which falls to the bottom. If the muriatic acid C
be added to a ſolution of no greater quantity of mercury in nitric acid, than could be diſſolved with effervefcence, the precipitate will be a ſalt of ſparing ſolubility in water, and highly corroſive, known by the name of muriate of mercury or corroſive ſublimate. But if the nitric acid be loaded with as much mer- D
cury as it can take up, and muriatic acid be added, the precipitate will be mild, and ſcarcely at all ſoluble in water, and is then called mercurius dulcis, or calomel.

Theſe, however, are not the uſual methods of pre- E
paring theſe ſalts. Corroſive muriate of mercury is made by a variety of methods, all which tend to combine the muriatic acid with the oxid of mercury. If the white ſaline maſs, produced by combining the ſulphuric acid with mercury (245, Y), be triturated with an equal weight of ſea-ſalt, and expoſed to heat in a cucurbit (129, X) the ſulphuric acid quits the oxid of mercury to combine with the alkali of the ſalt, while the muriatic acid thus diſengaged unites with the mercurial oxid, and forms the corroſive ſalt required. This is ſublimed by the heat, in a white maſs, cryſtallized in the form of needles.

F Corroſive muriate of mercury, triturated with mercury, abſorbs or unites with a quantity about two-thirds of its own weight. Sublimation renders the union more perfect, and affords ſweet muriate of mercury, or the mercurius dulcis of the ſhops.

G The oxiginated muriatic acid directly attacks and oxidates mercury, which it converts into corroſive ſublimate.

H Mercury combines with almoſt all metallic ſubſtances, and communicates to them more or leſs of its fuſibility. When theſe metallic mixtures contain enough of mercury to render them ſoft in a mean temperature, they are called amalgams or alloys.

I Lead is a white metal of a conſiderable blue tinge, not ſubject to be much corroded by expoſure to air or water, though the brightneſs of its ſurface, when cut or ſcraped, ſoon goes off. It is very ſoft and flexible; not very tenacious, and conſequently incapable of being drawn into fine wire. Under the hammer it is eaſily extended into thin plates, but its properties have not induced workmen to ſubject it to the ſame trials as gold, ſilver, and copper, and therefore its comparative malleability is not known. Its ſpecific gravity is 11,352. On the fire it melts long before ignition, at about the 540th degree of Fahrenheit's thermometer, at which period it begins to be oxidated, if air be preſent. In a ſtrong red heat it boils and emits fumes. If melted lead be poured into a box, previouſly rubbed with chalk, to prevent adheſion, and continually agitated, it will concrete into ſeparate grains, of conſiderable uſe in a variety of mechanical

chanical operations; or if it be poured into a mould, and turned out at the instant of cooling, a blow with the hammer will break the mass, and the symmetrical arrangement of the internal parts will be seen.

It forms alloys with arsenic, bismuth, antimony, mercury, tin, and zinc. It is soluble in most of the acids. It unites by fusion with phosphorus and sulphur.

The ores of lead are most commonly found among L earths of the calcareous or barytic kind. Oxids of lead, or calciform lead-ores, are either transparent or opake spars, or pulverulent, or ochreous masses of a reddish or brown colour. They are reducible by fusion with combustible matters. Lead is also found mineralized by the sulphuric and carbonic acid. Combined with the phosphoric acid it forms the ore called phosphate of lead, of a greenish colour. Sulphur is the usual mineralizer of lead. Of these the sulphuret of lead galena, or potters ore, is the most common. It is of a lead colour, but darker, and is for the most part formed in cubes of a moderate size, or grains of a cubical figure, with the corners cut off; its texture being granular. When antimony enters into the composition, the texture is radiated or filamentous. There are also pyritous and red arsenical lead ores, but the latter is very scarce. The sulphurets of lead frequently contain silver. It is not indubitably established that native lead has ever been found.

By oxidation, lead is converted into a dusky powder M called grey oxid of lead, or plumbum ustum; a

longer continued heat, with acceſs of air, renders it yellow, this product is called maſſicot or yellow oxid of lead, and after ſome days, of a bright red, called minium, or red oxid of lead. The heat for this purpoſe muſt not exceed a certain degree. A greater heat converts the oxid, by degrees, into a yellow flaky oxid, called litharge or ſemi-vitreous oxid of lead; and by a moderately ſtrong fire, it runs into a yellow tranſparent glaſs, which powerfully diſſolves metallic oxids (236, R); and unleſs combined with theſe, or earthy additions, corrodes and paſſes through common crucibles. This glaſs acts more ſtrongly on ſiliceous than on argillaceous earths, and is a principal ingredient in fine white glaſs. The oxids of lead decompoſe muriate of ſoda, and muriate of ammonia. Two parts of muriate of ammonia, and one of red oxid of lead, fuſed together, forms the beautiful pigment called patent yellow. Common ſalt may be ſubſtituted for muriate of ammonia.

N Sulphuric acid, by boiling, combines with lead into a ſaline maſs, called ſulphate of lead. Nitric acid unites with it nitrate of lead, which is a cryſtallizable ſalt. The ſulphuric acid, added to a ſolution of lead in the nitric acid, ſeizes the oxid, and falls to the bottom, forming the ſame compound as would have been produced by direct ſolution of lead. The muriatic acid, in the ſame manner carries down the lead, and forms a combination called muriate of lead, plumbum corneum, which is more ſoluble in water than muriate of ſilver. If, therefore, a lead ore be aſſayed for lead and ſilver, the ſolution of the ore in nitric acid may be

be precipitated by adding to it muriatic acid; both the ſilver and the lead will be precipitated, but the oxid of lead may be ſeparated from the oxid of ſilver. By a more copious ablution in water, the water diſſolves the oxid of lead and leaves the oxid of ſilver; or the ſilver may be ſeparated by liquid ammonia, which diſſolves the oxid of ſilver and leaves the oxid of lead (241, H).

The muriatic acid acts directly on lead, by boiling. O

The acetous acid diſſolves lead and its oxids. P White lead, or ceruſe, is made by rolling leaden plate ſpirally up, ſo as to leave the ſpace of an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is ſome good vinegar. The pots are to be covered and expoſed for a length of time to a gentle heat in a ſand bath, or by placing them in dung. The vapour of the vinegar, attaches itſelf to the ſurface of the plates, and corrodes them, by that means reducing them into ceruſe, which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly, till they are corroded through.

By ſolution of this compound in acetous acid, a Q cryſtallizable ſalt, called acetate of lead, or ſugar of lead, is obtained, which is the ſame as would with leſs facility have been procured by diſſolving lead directly in that acid. From this ſolution lead may be precipitated in a metallic ſtate by zinc.

Lead precipitates ſilver and mercury from their ſolution in nitric acid. If muriate of mercury and

 granu-

granulated lead be distilled together, mercury will pass over, and muriate of lead remain in the retort.

R Sulphur readily combines with lead, by the assistance of heat, and forms a compound, similar to the sulphureous lead ore.

S Oils and fats have a strong action on lead and its oxids. Litharge, or any of the other oxids of lead are copiously and entirely soluble in oils by boiling, which are thereby rendered thicker, and more drying. Linseed oil, thus impregnated with litharge, is much used by painters, under the name of drying oil. Many of the plasters used in surgery have for their basis oil thickened by boiling with oxid of lead.

T Lead in its metallic state unites with most metals. The alloy, called plumbers solder, consists of two parts of lead and one of tin. Lead may be separated from copper by eliquation, or melting by a heat too low to fuse the copper. It altogether rejects iron.

U Copper is a metal of a peculiar reddish brown colour, subject to tarnish; it grows black by long exposure to the air; and easily rusts by moisture. It is of very considerable hardness, tenacity, ductility, and malleability: and its elasticity is greater than that of any metal, except iron. From this last property, masses of this metal emit a loud and lasting sound when struck, and that, more especially, when of

V a proper figure (68, w). At a degree of heat, far below ignition, the surface of a piece of polished copper becomes covered with various ranges of prismatic

colours,

colours, the red of each order being neareſt the end which has been moſt heated; an effect, which muſt doubtleſs be attributed to oxidation, the ſtratum of oxide being thickeſt where the heat has been greateſt, and gradually thinner and thinner towards the colder part (1, 280). A greater degree of heat oxides this metal more rapidly, ſo that it contracts thin powdery ſcales on its ſurface, which may be eaſily rubbed off, the flame of the fuel becoming at the ſame time of a beautiful green or bluiſh colour. In a ſtrong white heat, greater than is neceſſary to w melt gold or ſilver, it melts and exhibits a bluiſh green colour.

Copper is ſometimes found native. Its ores are x either calciform, or oxids of a red, blue, or green colour, or ſulphurets, with more or leſs of iron, arſenic, or zinc. It is alſo found mineralized by ſulphuric or muriatic acids (178, w). Copper is extracted from its ores by repeated fuſions and roaſting, by which the ſulphur is driven off, and the other metals ſcorified. Lead is an uſeful addition for depriving it of the laſt portions of ſulphur. Silver is extracted from copper by eliquation (250, T) with lead, which carries the ſilver down with it. This proceſs cannot however ſeparate gold from copper. When the quantity of gold is ſuſpected to be too ſmall to be advantageouſly recovered by teſting, (236, R) it may be extracted by pulverizing the ſulphurated copper, ſulphur being added if required, and grinding the maſs with mercury, which amalgamates with the gold (235, Q).

Its ſpecific gravity is between 7,788 and 8,584, at a high temperature it burns with a green flame. It takes fire ſpontaneouſly in oxiginated muriatic acid gas. The galvanic ſpark inflames it. It combines with phoſphorus and ſulphur.

Y Sulphuric acid, highly concentrated and boiling, diſſolves copper, and by evaporation affords blue cryſtals (178, v) of ſulphate of copper. By cementation of copper with ſulphur, part of the maſs becomes ſoluble in water, and affords the ſame ſalt.

Z Nitric acid diſſolves copper with great violence, and forms a deliqueſcent ſalt, called nitrate of copper. The ſolution is blue, as are alſo the cryſtals. This ſalt, dried and rolled up in tin-foil takes fire ſpontaneouſly.

A Muriatic acid likewiſe diſſolves this metal, and forms a deliqueſcent ſalt, called muriate of copper.

B Verdigris or acetate of copper is made by ſtratifying copper plates with huſks of grapes after the juice has been preſſed out, the remaining acid forming this ſub-
C ſtance by oxidating the metal. Verdigris rediſſolved in diſtilled vinegar and purified from adhering impurities, when cryſtallized, is impropely called diſtilled verdigris.

D Acetate of copper may be deprived of its acid by
E diſtillation with ſulphuric acid. The acetous acid, thus recovered, is called radical vinegar (217, 2).

F When copper may be ſeparated from any acid by the addition of ammonia, if the ammonia be added in greater quantity than is ſufficient for the purpoſe, the

the alkali rediſſolves the oxid, and gives the liquor a blue colour.

Liquid ammonia diſſolves copper, if the acceſs of air be permitted. The ſolution is of a fine blue, and yields on evaporation, a ſaline maſs of the ſame colour. It is obſervable that the ammoniacal liquid remains colourleſs while the air is prevented from communicating with its ſurface, but that the blue colour extends gradually from the ſurface downwards, when the veſſel is opened. A circumſtance well explained from the conſideration that the oxigen of the air combines with the copper and oxidates it, in order to render it ſoluble in the ammonia. G

Copper mixes with the other metals. The compoſitions moſt generally in uſe, in which copper enters as the principal part, are braſs and bell-metal. H

Braſs is compoſed of copper and zinc. According to the proportion of zinc, the braſs is of a yellower and paler colour than copper, and when the zinc greatly abounds it is white. Braſs is very ductile and malleable when cold, but brittle when hot. It is harder, more ſonorous, and not ſo liable to ruſt as pure copper; and is alſo more fuſible, and leſs ſubject to ſcorify in a moderate heat. Theſe properties, added to the beauty of its colour, render it a very valuable material in the arts. I

The fineſt braſs is not made by the fuſion of copper and zinc, but by the cementation of granulated copper with pulverized calamine and charcoal. The calamine which is an ore containing zinc in an oxidated ſtate, parts with its zinc in the form of vapour K

when revived by the charcoal; and this volatile metal combines with the copper. The process lasts eight or ten hours, or even some days, according to the quality of the calamine, at the end of which, by an increase of heat for a short time, the brass is fused into a mass at the bottom of the crucible. The quantity of zinc in good brass, may be about one third.

L Bell-metal is composed of copper alloyed with tin. According to the proportion of tin the compound becomes paler than copper, and when the tin amounts to one third of the mass, it becomes of a very beautiful yellowish white. It is remarkable that zinc, which is scarcely at all malleable, should unite with copper into the malleable compound brass; and on the contrary, the two malleable metals, tin and copper, compose bell-metal, which is so brittle, that it may be reduced to powder. The specific gravity of bell-metal is a circumstance equally singular; for in most proportions of the mixture it is about as heavy as the heaviest of the two metals, copper; and when the tin is about one third, its density is actually greater than that of copper *. The extreme hardness and sonorousness of this compound, together with its being less subject to alter by exposure to the vicissitudes of the air, than any other cheap metallic compound possessing the same properties, have recommended it in the fabrication of various utensils and articles; as cannon, bells, statues, &c. in the composition of which, other metals, however, are mixed in various propor-

* Lewis on Newman, 1, 97.

tions, according to the fancy or the experience of the artist.

The attention of the philosopher is more particularly directed to the mixture of copper and tin, on account of its being the substance of which the speculums of reflecting telescopes are made. For this purpose there is required a metal capable of an exquisite polish, hard enough to receive and retain a figure accurately suited to the regular reflection of light, and not subject to lose its polish or figure by the action of air and the vapours usually floating therein. Such a composition, it must be confessed, is still a desideratum; but the experiments and practice of the best artists shew, that pure copper alloyed with pure tin, affords a metal equal at least to most of the less simple mixtures given in books. As to the proportions, it is found that a small addition of tin renders the colour of copper whiter, and at the same time hardens it considerably. These effects are more and more prevalent while the dose of tin increases as far as a certain point. Fourteen ounces and a half of tin to two pounds of copper, is a good composition for mirrors. One third part tin produces a whiter colour, but is too hard to be worked in the usual methods of grinding. If the dose of tin be greatly increased, a softer metal of a bluish white colour is obtained, which bears and retains a good polish and figure, but does not seem equal to the yellowish white. Some care and attention are required in casting mirrors, that they may not prove full of microscopic pores by the intermixture of oxid. For this metal is easily reduced to an oxid, and burns

with

P with a purple flame in a ſtrong red heat. To prevent this, the copper muſt firſt be fuſed in a melting-pot, larger than ſufficient to contain the whole, and whoſe upper part is filled with pulverized charcoal, and the tin afterwards added; and when the mixture is completed, the whole muſt be ſuffered to cool, nearly to concretion, before it is poured out. Or, which is ſtill better, it may be poured out and again melted with a low heat, ſuch as is merely ſufficient for the purpoſe. Among various pieces caſt out of the ſame fuſion, the latter proved always cleaner, better adapted to the mould, and of a more uniform texture when poliſhed. The quantity of about one fiftieth part of arſenic added at the laſt fuſion greatly improves the denſity of the metal.

Q Iron is a metal of a bluiſh white colour, more or leſs dark in various ſpecimens, ſubject to ruſt by expoſure to air and moiſture. Its tenacity, ductility, and malleability are very great; and it exceeds every other metal in elaſticity and hardneſs. The appearance of priſmatic colours (251, v) on its poliſhed ſurface takes place long before ignition. It may be ignited by a quick ſucceſſion of blows with a hammer. Struck with a flint it emits decrepitating ignited particles, ſuch as can be obtained from no other metal by the ſame means. It is eaſily oxidable by fire, but is abſolutely infuſible when pure. It burns vividly in oxigen gas.

R In a white heat, iron appears as if covered with a kind of varniſh, and in this ſtate two pieces applied together will adhere and may be perfectly united by forging. This operation, which is peculiar to iron and platina,

platina, is called welding. Iron is thought to be the only ſubſtance in nature that has the property of becoming magnetical. Such other bodies as have that property, poſſeſs it in a very ſlight degree, and it may ariſe from iron contained in them, as far as experiments have yet unequivocally ſhewn.

Iron is more abundant and more univerſally diffuſed than any other metallic body. Few ſands, clays, ſtones, or waters of rivers, ſprings, rain, or ſnow are perfectly free from it. The parts of animal and vegetable ſubſtances have been alſo obſerved to contain it. Native malleable iron has been found, though rarely. Its ores are either purely calciform or oxids, as in ochres and hæmatites; or the calces are mixed chiefly with earths, as in ſpars, jaſper, boles, baſaltes, micas, &c.; or the iron is mineralized with ſulphur, forming ſulphurets, as in pyrites, (171, c) with arſenic in the white pyrites, or with both; with bitumen in the coal ore; or combined with the ſulphuric acid in native vitriol or ſulphate of iron.

The ores of iron, after roaſting, are ſmelted in furnaces of various magnitudes and forms. Some are thirty feet in height, their internal ſhape being nearly the fruſtum of a cone, whoſe larger baſe is uppermoſt. Near the bottom is an aperture, for the inſertion of the pipe of large bellows, worked by water, or of other machines for producing a current of air, and alſo holes to be occaſionally opened to permit the ſcoria and the metal to flow out, as the proceſs may require. Charcoal or coke, with lighted bruſhwood, is firſt thrown in, and when the whole inſide of the furnace has acquired

quired a ſtrong ignition, the ore is thrown in by ſmall quantities at a time, with more of the fuel, and commonly a portion of lime ſtone, as a flux. The ore gradually ſubſides into the hotteſt part of the furnace, where it becomes fuſed, and the metallic particles revived by the coal paſs through the ſcoria, and poſſeſs the lower place. The quantity of fuel, the additions, and the heat, muſt be regulated in order to obtain iron of a good quality; and this quality muſt likewiſe, in the firſt product, be neceſſarily different, according to the nature of the parts that compoſe the ore.

v The beſt caſt iron, or iron as much freed from heterogeneous matters as the uſual proceſs of ſmelting can effect it, is ſcarcely at all malleable, and not ſo hard, but that it may be filed and turned in a lathe. If this be kept in fuſion for a conſiderable time, it boils, and much ſcoria is ſeparated; and by repeated blows of a large hammer on the maſs, when nearly at the melting heat, more extraneous matter is forced out, and it is rendered malleable. In this ſtate it is much ſofter than before, and of a fibrous texture.

w Steel is iron combined with carbon; it is ſoft, tough, and malleable. It is harder than any of the metals when heated, and if ſuddenly cooled, it becomes ſtill harder, more elaſtic, leſs pliable, and brittle, but when heated again and cooled ſlowly, it becomes again, ſoft, pliable, and ductile. It may be known chemically by letting fall on it a drop of nitric acid, which produces on ſteel a black ſpot, whereas the ſpot formed by nitric acid upon iron is a whitiſh grey. The iron run

from

from some German ores is found to be a good steel, when forged only to a certain point. But steel is usually made by cementation from the best forged iron with matters chiefly of the inflammable kind. Two parts of pounded charcoal and one of wood ashes is esteemed a good cement. If small iron bars are bedded separately, or apart from each other, in this cement, in a closed crucible, and kept in an equal red heat for eight or ten hours, at the end of which time they are found to be converted into steel. The process requires four or five days in the large way. If the cementation be continued too long, the steel is brought to a state resembling cast iron, being rendered excessively brittle, incapable of being welded, and apt to crack and fly in forging.

It is a valuable property of steel, that though it is sufficiently soft when gradually cooled, to be formed without difficulty into various tools and utensils, yet it may be afterwards rendered more or less hard, even to an extreme degree, by simply plunging it, when heated, into cold water. The hardness produced, is greater in proportion as the steel is hotter and the water colder. The colours that appear on the surface of steel slowly heated, are yellowish white, yellow, gold colour, purple, violet, deep blue, yellowish white, after which the ignition takes place. These signs direct the artist in reducing or tempering its hardness. Ignited steel quenched in water, proves excessively hard and brittle, but it may be reduced to the required degree of softness by heating it till it exhibits a known colour. Soft steel

ſteel has a greater ſpecific gravity than that which is hardened.

Y Crude iron, by cementation with animal coal, may be brought into a ſtate reſembling ſteel, and capable of being hardened by immerſion in water; and a farther continuation of this proceſs carries it beyond that point, ſo that it reſembles forged iron. But this management is much leſs effectual than forging, probably becauſe the impurities of the crude iron are not removed by it.

Z Tools and other articles wrought in forged iron, are often cemented with a compoſition of burned leather, horns, or the like ſubſtances for a ſhort time, by which a very thin ſtratum of the external part is converted into ſteel, and is hardened by immerſion in water. This is called caſe-hardening.

A The chief differences in iron appear to depend on the preſence or abſence of carbon (169, V). When caſt iron is diſſolved in the ſulphuric acid, a reſidue remains untouched, which is found to conſiſt chiefly of carbon, hydrogen gas being at the ſame time extri-
B cated (179, A). Steel in the ſame circumſtances affords leſs carbon. Malleable iron, ſimilarly treated, leaves ſcarcely any reſidue. It is therefore ſeen that caſt iron conſiſts of the metal combined with a great portion of carbon not ſufficiently deoxidated to ſuch a degree as may be probably neceſſary (233, I) in order to be capable of ſuch an union. Steel is iron, combined with carbon: the proportion of the latter has not yet been accurately aſcertained; it is ſaid to contain

only

only a few hundredth parts of carbon. Pure forged iron is the metal itſelf alone.

The iron obtained from various ores, or by va- C
rious proceſſes; is found to differ in its qualities in ſeveral other reſpects, the cauſes of which have not yet been ſufficiently examined. In particular, the iron of certain ores, eſpecially if the fuſion in the ſmelting furnace has not been continued a ſufficient time, has the quality of breaking in pieces under the hammer when ignited, but being malleable when cold. This is called hot-ſhort iron, and is ſuppoſed to contain arſenic and ſulphur.

Such iron as contains the phoſphoric acid, is mal- D
leable when ignited and brittle when cold. This is called cold-ſhort iron.

The ſulphuric acid diſſolves iron readily, and forms E
ſulphate of iron (178, U). The metal of this ſalt while in ſolution is farther oxidated by the contact of air, and is by that means rendered leſs ſoluble in the acid (233, I). A quantity of oxid, therefore, gradually falls to the bottom in that caſe, and the liquor, as well as the cryſtals, obtained from it by evaporation, are paler.

Dilute nitric acid diſſolves iron and forms a ſaline F
combination incapable of cryſtallizing. Strong nitric acid attacks and rapidly corrodes and oxides a conſiderable quantity of the iron, which falls to the bottom.

Muriatic acid likewiſe diſſolves iron, and forms G
a cryſtallizable ſalt.

The Pruſſic acid combined with an alcali precipi- H
tates

tates iron from its solutions in the form of Prussian blue (208, w).

I Galls and other astringent vegetables precipitate iron from its solution in the form of a deep blue or purple fecula, of so intense a colour as to appear black. The infusion of galls, and also the Prussian alkali, are tests of the presence of iron by virtue of the precipitates they throw down. Acids dissolve the black precipitate caused by galls: alcalis convert it into a brown oxid.

K A good and durable black ink may be made by the following directions: To two pints of water add three ounces of the dark coloured rough skinned Aleppo galls in gross powder, and of rasped logwood, green copperas, or sulphate of iron and gum arabic, each an ounce. This mixture is to be put into a convenient vessel, and well shaken four or five times a day, for ten or twelve days, at the end of which time it will be fit for use; though it will improve by remaining longer on the ingredients. Vinegar instead of water makes a deeper coloured ink; but its action on pens soon spoils them.

L Iron readily combines with sulphur. If a bar of iron be strongly ignited and a roll of sulphur be applied to the heated end, it will combine with the iron and form a sulphuret of iron, which will drop down. A vessel of water ought to be placed beneath, for the purpose of receiving and extinguishing it, as the fumes would otherwise be inconvenient to the operator. It also combines with phosphorus.

M If a mixture of five or six pounds of filings of iron be moistened with a sufficient quantity of water to form a paste,

a paste, it will in a certain time swell, become hot, melt, fume, and even take fire. The residuum furnishes sulphate of iron. This process is similar to the decomposition of the martial pyrites. The water and air are necessary to enable the acid to act on the iron.

Iron may be allayed with all metals, except lead. The combination of iron with mercury may be accomplished according to Dr. Arthur Aikin, by making first an alloy of zinc and mercury with iron filings, and then adding muriate of iron; a decomposition now takes place, and there is produced a muriate of zinc and an alloy of iron and mercury, which by kneading and the aid of heat assumes a metallic lustre. A coating of tin defends iron from rusting by the action of the air and other solvents, and is accordingly much used.

Tin is a metal of a yellowish white colour, not subject to rust, though its scraped or polished surface soon loses its brightness. It is not quite so soft as lead, has not much tenacity, and is the least heavy of any of the metals. Its specific gravity is from 7.291 to 7.500. Under the hammer it is beat into leaves of about the thousandth part of an inch in thickness, and might easily be beaten to less than half that thickness, if the purposes of trade required it. Long before ignition, it melts at about the 420th degree of Fahrenheit's thermometer, and by continuance of the heat, slowly oxidates and becomes converted into a white powder. Tin, like lead, is brittle when heated almost to fusion, and being broken by the blow of a hammer, exhibits a grained or fibrous texture. It may also be granu-

lated by agitation, at the time of its passing from a fluid to a solid state (247, K). Its oxids resist fusion more than that of any other metal, and from that property it is useful to form an opake white enamel, when mixed with glass in fusion.

P The largest quantities of tin are found in the county of Cornwall in England. It is also found in Saxony, Bohemia, and the peninsula of Malacca in the East Indies; but rarely in any other countries in sufficient quantities to pay the charges of working. Native tin is seldom met with. The ores of tin are almost always oxids of that metal in a crystallized form, bedded commonly in a siliceous matrix. Such are the white tin spar, the opake brown or black ore, the garnet ore, which abounds with iron, and the tin stone. These are all much heavier than any unmetallic substance. Tin has been found in Siberia, united with sulphur, forming tin pyrites.

Q Tin ores, when impure, are cleansed from heterogeneous particles by pounding and washing. A slight previous roasting renders the stony admixtures more friable; and when arsenic is contained in the matrix, it is driven off by a strong heat, continued for a short time, the ore being frequently stirred to prevent its fusion. In the smelting, care is taken to add a larger quantity of charcoal than is commonly used in other fusions; and, to avoid a greater heat than is necessary to reduce the ore, in order that the loss of metal, which would otherwise happen by oxidation, may be prevented as much as possible.

R Concentrated sulphuric acid dissolves tin in a boiling

heat.

heat. During the ſolution, ſulphureous acid gas eſcapes.

Nitric acid acts very powerfully on tin. To obtain a perfect ſolution, the metal muſt be added a very little at a time, and all heat avoided; for if much tin be put in at once, the oxidation takes place with great rapidity and heat, and the metal falls to the bottom in the form of a white powder, inſoluble in acids (233. 1); and of difficult reduction. The ſalt, formed by the union of tin with the nitric acid, burns and ſparkles in a red heat. s

If cryſtals of nitrate of copper (252, z) be groſsly pulverized, moiſtened, and rolled up in tin-foil, the ſalt deliqueſces, and the nitric acid begins to act on the tin with heat, nitrous gas is emitted, and the tin takes fire. T

Muriatic acid diſſolves tin with the aſſiſtance of heat, and affords cryſtals by evaporation. If corroſive ſublimate be added to tin, divided by previous amalgamation with mercury, the muriatic acid combines with the tin, and comes over by diſtillation, in the form of a ſtrong ſmoking liquid, or fuming oxiginated muriate of tin, which if diluted with water, grows opake, and depoſits oxid of tin. u

Nitro-muriatic acid diſſolves tin directly, and when loaded with that metal, has a gelatinous appearance. This ſolution is uſed by dyers for heightening the colours of cochineal, gum-lac, and ſome other red tinctures, from a crimſon to a bright ſcarlet, in the dying of woollens.

Tin combines with ſulphur by fuſion, and forms a w

x brittle maſs leſs fuſible than pure tin. If the amalgam of tin, with $\frac{1}{4}$ of its weight of mercury, be ſet to ſublime with $\frac{1}{2}$ part of ſulphur and muriate of ammonia, each equal in weight to the mercury, the whole being previouſly well triturated with a little water, a ſparkling gold coloured ſubſtance is obtained, which conſiſts of tin and ſulphur, and is called aurum muſivum. The proceſs is thus explained: in the firſt amalgamation and ſubſequent trituration of the mercury and tin, both are partially oxidated. On heating this alloy in contact with muriate of ammonia and ſulphur, the tin and muriatic acid decompoſe the water, the tin becomes oxidated at the expenſe of the oxigen of the water, and this oxid is diſſolved by the muriatic acid. The liberated ammonia of the muriate of ammonia diſſolves a portion of ſulphur, and forms ſulphuret of ammonia, which being diſengaged cauſes the white fumes. On increaſing the heat the muriate of tin is decompoſed. The oxid of that metal combines with a portion of ſulphur and forms the yellow ſulphurated oxid of tin, or aurum muſivum.

y Tin unites with all the metals. Clean iron plates, dipped in melted tin, become covered with a thin coating of that metal, and form a very uſeful material for making wholeſome kitchen utenſils, and other articles. In performing this buſineſs it is found neceſſary, either to dip the clean iron previouſly in a ſolution of muriate of ammonia, or to keep the ſurface of the tin covered with fat and pitch, in order that the appoſition of the two metals may not be prevented by the

film

film of oxid that the contact of air might form on their surfaces. These plates, which possess the cleanliness of tin, added to the rigidity of iron, are much used. In England they are called tin plates. In the same manner stirrups, bridle-bits, buckles, &c. are tinned.

Pewter is a compound metal, whose basis is tin. Z
The best pewter consists of tin allayed with a quantity not exceeding one twentieth of copper, or other metallic bodies, as the experience of the workman has shewn to be most conducive to the improvement of its hardness and colour. The inferior sorts of pewter contain much lead, have a bluish colour, and are soft.

Useful compounds are made with tin, and a large A
proportion of copper.

Bismuth is a yellowish or reddish white semi-metal. It is somewhat harder than lead, it is easily broken, and even reduced to powder by the hammer. The internal face, when broken, appears composed of large shining plates, disposed in a variety of positions. It melts at the 460th degree of Fahrenheit. Thin pieces are considerably sonorous. Its specific gravity is 9.822.

This metal is often found native. Its ores are either C
oxids or sulphurets.

Bismuth is scarcely soluble in sulphuric acid, and still D
less in muriatic acid. Nitric acid, or nitro-muriatic acid, dissolves it. The addition of water precipitates its oxid, the oxid however is soluble by a more copious addition of water; this is the criterion by which bismuth is distinguished and purified from all other metals. This white oxid, called magistery of bismuth,

or Spanish white, is used as a paint for the complexion, which however it gradually impairs.

E Most metallic matters unite with bismuth, and are rendered more fusible by the addition. It is used in making pewter, printers types, solder, &c. The great fusibility of the mixture of bismuth, tin, and lead, renders it of use in making collars for the axles of some mechanical instruments to run in. It combines with sulphur and phosphorus.

F Nickel is a metal of a reddish white colour, of great hardness, scarcely yielding to the file, and of an uniform texture. It is very difficult to purify it, and is supposed, even when as pure as it has hitherto been obtained, to contain iron, as it is magnetical. It is brittle, and scarcely more fusible than pure iron.

G The sulphuric and muriatic acids do not easily attack this semi-metal. The nitric acid and nitro-muriatic acid dissolve it readily. Its solutions are deep green. Its specific gravity is nearly 9. It unites to phosphorus and sulphur.

H Arsenic is between a tin white and lead grey colour, subject to tarnish, and become black by exposure to air; very brittle, and of a lamellar texture. By heat it sublimes in the form of an oxid, if air be present and partly unaltered. The fumes have an offensive smell, resembling garlick, and are said to be dangerous.

I The white arsenic met with in commerce is brought chiefly from the cobalt works in Saxony, for making zaffre and smalt. The arsenic contained in great quantity in cobalt ores, is driven off by long torrefaction. These fumes pass into and adhere to the sides of a very long

long chimney, constructed for that purpose. This arsenic is an oxid of the metal, oxidated in the first degree; it is therefore called arsenious acid.

The metallic arsenic is obtained from this oxid, either by quickly fusing it together with twice its weight of soft soap and an equal quantity of mineral alkali, pouring it out, when fused, into an hot iron cone; or by mixing it, in powder, with oil, and distilling the whole gradually to dryness. The metal sublimes towards the end. This process is too offensive to be made but in the open air. K

Arsenious acid previously divided by solution in boiling muriatic acid, is further oxidated by repeatedly pouring nitric acid on it, and distilling it off, and at last raising the heat to ignition, that it becomes a perfect acid, in the form of a concrete white mass, very soluble in water, and possessing peculiar properties. This is the arsenic acid. L

The oxigenated muriatic acid likewise affords oxigen to the arsenious acid, and produces the arsenic acid *. M

The sulphuric acid dissolves the metallic arsenic by boiling. The muriatic acid and nitro-muriatic acid also dissolve it by heat. Nitric acid oxidates it. N

Arsenic in any form is a strong poison. O

Cobalt is a metal of a bluish grey colour, of considerable hardness, and very brittle. When well purified it is nearly as infusible as iron. Its ores are either P

* These processes are amply described in Scheele's Chemical Essays. London, 1786.

oxids or calciform, or it is mineralized with the ſul-phuric or arſenic acid. They moſtly abound with arſenic, and contain biſmuth, iron, or other metallic matters.

Theſe ores have not been found in plenty, or at leaſt worked to advantage, except in Saxony. They are valued for the beautiful blue they impart to glaſs, and are manufactured on the ſpot into zaffre and ſmalt. The firſt conſiſts of the oxid of cobalt ſimply mixed with pulverized flints, moiſtened and preſſed into caſks. The latter is the ſame oxid fuſed into glaſs with vitrifi-able earth and alkali, and reduced to a fine powder, by quenching in water and levigation, or rolling in a mill.

R Cobalt is eaſily ſoluble in the nitric acid or in nitro-muriatic acid, to which it imparts a red colour. The ſolution when diluted with water forms a ſympathetic ink, which when written with on paper is inviſible, but appears of a green colour when heated, and diſappears again when cold. The ſulphuric acid ſcarcely acts on it, unleſs boiling and highly concentrated. The mu-riatic acid has no action on the metal, but diſſolves the oxids. It forms a blue ſympathetic ink.

S Zinc is a white ſemi-metal, not ſubject to ruſt in the air, harder than either lead or tin, malleable in a certain degree and laminable, and ſo tough that a thin piece may be bent ſeveral times backward and forward before it breaks. Its fracture exhibits ſhining facets. Some time before ignition it melts; when ignited it becomes covered with a white oxid, and on the heat being raiſed and the ſurface of the metal uncovered, it

burns

burns with a very bright yellowiſh green flame, at the ſame time that part of the oxid is driven up in the form of a white ſmoke, which floats in the air.

The ores of zinc, are either oxids, as the zinc-ſpar, r
and calamine; or mineralized with ſulphur, as in pſeudo-galena or black jack, and blends of various colours. The ſulphureous ores require torrefaction. Zinc is obtained from its ores by diſtillation with charcoal, in cloſed-veſſels in a reverberatory furnace, their conſtruction being peculiarly adapted to preſerve this volatile and eaſily inflammable metal from being diſſipated or oxidated.

Zinc is readily diſſolved in acids. Sulphate of u
zinc or white vitriol is the only ſaline combination of this metal found in commerce.

Sulphur has no action on this ſemi-metal: whence v
it is eaſily purified, by burning ſulphur on its ſurface when in fuſion. Theſe two ſubſtances are united in ores by the medium of iron. It unites to phoſphorus.

Zinc is chiefly uſed in making braſs and other w
metallic mixtures of the like nature. It is likewiſe uſed as a ſolder, known by the name of ſpelter. Its ſpecific gravity is 7.190: it precipitates the greater number of metals from their ſolutions. Gold, ſilver, platina, nickel, tin, mercury, and copper unite with it. It takes fire ſpontaneouſly in oxigenated muriatic acid gas.

Antimony is of a ſilvery white, not ſubject to ruſt, x
very brittle, and of a ſcaly or plated texture. It melts ſoon after ignition, and by a continuance of the heat

becomes oxidated, and riſes in the form of white fumes. By a more moderate heat it is converted into a grey oxid fuſible into a kind of glaſs.

y The moſt common ore of this metal is the ſubſtance, called ſulphuret of antimony. It contains ſulphur in combination with antimony, is of a dark bluiſh metallic colour, and its fracture reſembles long ſhining needles. The metal may be obtained by torrefaction, by which the ſulphur is driven off, and ſubſequent fuſion with inflammable matters. In the ſmall way, four parts of ſulphuret of antimony with three parts of tartrite of potaſh, and one and a half of nitre, are thrown a little at a time into a red hot crucible, and the heat raiſed at the end ſo as to fuſe the maſs. The detonation conſumes much of the ſulphur, and the coaly matter of the tartrite of potaſh revives a conſiderable part of the oxid which is found at the bottom of the crucible. Or the native antimony may be thrown on half its weight of ſmall pieces of iron or nails, firſt made white hot in a crucible, and the heat being ſuddenly raiſed, after having covered the crucible, the maſs melts, metallic antimony being at the bottom, and the iron combined with the ſulphur at the top.

z Moſt of the acids diſſolve antimony though difficultly. The muriatic acid has very little effect on it; but it is ſoluble in a conſiderable degree in nitro-muriatic acid, conſiſting of ſeven parts nitric and one muriatic acid, or in a mixture of the ſulphuric and muriatic acid, or even of the ſulphuric and nitric acids.

A Much labour has been beſtowed on this metal by the

the alchemiſts. It furniſhes ſome very powerful remedies, but its medical preparations require the greateſt care and attention; becauſe variations apparently of ſmall importance in the proceſſes are ſufficient to render its effects uncertain, and even highly dangerous.

Antimony is uſed in various metallic mixtures, for B printing types, ſpeculums, &c. It burns in oxigenated muriatic acid gas.

Mangeneſe is a metal of a duſky white colour when C newly broken, which grows brown by ſpontaneous oxidation on expoſure to the air. It appears to be leſs fuſible than iron, the larger pieces being ſcarcely ever globular. It is very hard and brittle, and becomes ſpontaneouſly oxidated in the air, ſo as to fall ſometimes into a browniſh black powder, heavier than the metal; a circumſtance which does not happen when it is incloſed in a dry, well corked bottle, or preſerved under oil or ſpirit.

Black mangeneſe is the oxid of this metal. D The colour is either white, grey, brown, or black, according to its leſs or greater oxidation, and the nature of the ſubſtances it may be contaminated with, of which iron is the chief. The brown or black oxid is too much oxidated to be ſoluble in acids, and has leſs attraction for oxigen than any other ſubſtance.

If a globule of phoſphate of ſoda and ammonia E or ſalt be melted on a piece of charcoal, by means of the blow-pipe, and a ſmall portion of the black oxid of mangeneſe be added, a glaſs will be formed of a

bluiſh

bluish red, or if the proportion of manganese be greater, of a full red. The tinge will however totally disappear if the fusion be continued with the interior or well defined apex of the flame. The brown or exterior part of the flame restores the colour. And this may be repeatedly done. The smallest particle of nitre added to the clear glass instantly restores the red colour: but metallic oxids discharge it, though these communicate each a tinge peculiar to itself.

The explanation of these facts appears to be this: the proper tinge communicated to glass by oxid of manganese, when highly oxidated, is red, but manganese with a less portion of oxigen is colourless. The fusion by the interior apex may be considered as a fusion in a close vessel, because the surrounding flame defends the globule from the contact of the air on the greater part of its surface. The reduction effected by the charcoal is therefore permanent, and produces the effect of rendering the globule transparent. But when the exterior flame is used, this is not the case; for the circumambient air, touching the globule in a much larger part of its surface, combines with it more speedily and in a greater quantity, than the small surface of contact between the globule and the charcoal is capable of absorbing. The colour therefore returns. The oxigen of the nitric acid in nitre oxidates the manganese. Metallic oxids, as well by the coaly matter they often contain, as by their own nature, are more disposed to perfect combustion than

the

the oxid of manganese, and therefore destroy the red colour. That these changes do not depend on the greater or less quantity of combustible matter that may be supposed to be imparted by the interior or exterior apices of the flame, is clear, from the changes not taking place when the globule rests on a support of pure gold or silver.

The same phenomena with small variation take place in other glasses. Hence a principal use of manganese is made by the glassmakers, in clearing their glass from the green tinge imparted to it by oxid of iron, from which they cannot with sufficient facility free the materials they use. The green colour arises from iron not sufficiently oxidated; manganese being therefore added in a certain dose, affords enough of oxigen to render the glass colourless. But if the dose be not duly proportioned, either its own red colour or the green will prevail; the latter of which is thought to be the best.

A remarkable effect of combustion from the oxigen in the oxid of manganese, is seen in the ore called black wad, from Derbyshire. It is a brown pulverulent mass, and used as a pigment. If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour, and then two ounces of linseed oil be gradually poured on it and loosely mixed, in somewhat more than half an hour the mixture will grow gradually hot, and at last burst into a flame. This effect seems to be analogous to the inflammation of oils by nitrous acid.

The

H The black oxid of manganese is sparingly taken up by the sulphuric acid, and this portion seems to be that which had not been well oxidated; for the remainder altogether rejects the acid. That this oxid is insoluble from an over dose of oxigen, is rendered clear, by adding sugar, honey, or any combustible substance, as by that means the solution is promoted and completed. The metals, not excepting even gold itself, produce the same effect.

L The nitric acid dissolves manganese with effervescence, occasioned by the production of nitrous air. A small residue is left. This acid acts very sparingly on the black oxid.

M The muriatic acid dissolves manganese and also the oxid. It likewise takes up the black oxid, which communicates to it a red colour, and gives off as much oxigen to the acid as is necessary to its solution. Part of the acid becomes converted into oxigenated muriatic acid, which takes the gaseous form, and flies off in yellow vapours.

N Tungsten or wolfram * is a brittle metal of a steel colour. Its specific gravity exceeds that of every other body in nature, except platina and gold; and it has not been fused into any mass of considerable magnitude, being more refractory than manganese.

O The ores of this metal are the tungstate of lime, a ponderous substance of a grey colour and lamellar tex-

* The discoveries of Scheele, Bergman, and the De Luyarts, are to be found in "A Chemical Analysis of Wolfram." Printed in London in the year 1785.

ture, containing the metallic oxid, or acid united to about its own weight of calcareous earth: and wolfram, or tungstate of iron and manganese, a mineral of a still greater specific gravity, of a brownish black, always opake, internally shining, almost like a metal, and of a crystallized form. This last is abundant in Cornwall, it contains about two thirds oxid of wolfram, together with the black oxid of manganese and oxid of iron. P

If pounded wolfram or tungsten be digested in the muriatic acid, the manganese and iron of the former, or the calcareous earth of the latter, will be taken up in part, or extracted from the external parts of the molecules. The residuum, after edulcoration with water, being digested with liquid ammonia, the oxid of wolfram, or acid, will be taken up in part, or extracted from the surface. The residue, after edulcoration, will be again acted upon by the muriatic acid, which seizes another stratum of particles that were in the former digestion defended from its action by the oxid of wolfram, which the digestion in liquid ammonia has removed. Ammonia being again applied, and the alternation continued for many vicissitudes, the mineral becomes almost entirely dissolved; the portions of acid contain either the oxids of manganese and iron, or calcareous earth, according to the mineral made use of; and the ammonia contains the oxid or acid of tungsten. The addition of nitric acid to this last precipitates a salt, consisting of the oxid of tungsten, ammonia, and nitric acid. This salt is soluble Q R

in water, though ſparingly, and has acid properties. The firſt diſcoverers, Scheele and Bergman, called it acid of tungſten. It is however a triple compound.

s Fuſion of the ore with potaſh, with ſolution in diſtilled water, will afford a combination of the oxid of tungſten with the alkali. This being diſſolved in water and filtered, may be deprived of the alkali by the addition of nitric acid. The tungſten oxid precipitates. The adhering acid may be driven off by heat, and leaves the pure oxid of tungſten of a brimſtone yellow. The ſame oxid is alſo obtained by heating the precipitate from ammonia, the nitric acid and the alkali being driven off.

T The pure oxid is not ſoluble in water, but makes, by trituration, an emulſion of ſufficient ſubtlety to paſs the filtre, and which does not entirely ſubſide in three months. It has not this effect with the ſulphuric, nitric, and muriatic acids. It is completely ſoluble in
U alkalies, by the moiſt as well as the dry way. A ſolution in water, and alſo in ammonia, of the precipitate by nitric acid, from the ammonia being added to lime-water, regenerates tungſten, the acid and alkali being found in the ſuperfluent liquor.

V From the ſtrong diſpoſition of the oxid of tungſten to unite with alkalis and with earths, and its inſolubility in acids, it has been conſidered as a metallic acid.

V By treatment in a crucible with charcoal, with a ſtrong heat, the oxid of tungſten is ſaid to be revived into a metal, being a brown maſs, conſiſting of a congeries of metallic globules, with a loſs of two fifths

of

of its weight. Oxidation turns it yellow as before, and its weight bcomes augmented about one fourth.

This metal is inſoluble in ſulphuric and muriatic w acids. The nitric acid, and nitro-muriatic acid, de-oxidate it, and convert it into the yellow oxid (208, s). It mixes with other metals, and forms peculiar alloys. Its oxids tinge glaſs.

Molybdena is a mineral ſubſtance, reſembling plum- x bago, but its laminæ are larger, brighter, and in ſome degree flexible, ſo as to be very difficultly reduced to powder. In an open fire it is almoſt entirely volatile. It is compoſed of ſulphur combined with a metal. No acids act on it but the arſenic and nitric. The firſt combines with its ſulphur, and forms orpiment: the latter, diſtilled from it, communicates oxigen, and forms the molybdic acid. This laſt acid may be waſhed off with water, which at the ſame time carries off a portion of the acid of molybdena.

This acid is in a white dry form, very ſparingly y ſoluble in water. It has all the general properties of acids, and others peculiar to itſelf. It is precipitable from its ſolution in water by Pruſſiate of potaſh. Diſ-tilled with three times its weight of ſulphur, it again produces molybdena.

It has been reduced into a metallic form. Mr. z Hatchett * has given a full analyſis of the above ore, and pointed out many of the properties of the molyb-dic acid, &c.

Tellurium is found in the white gold ore of Fatzebay,

* Phil. Tranſ. 1796. Analyſis of the Carynthian Molybdate of Lead.

commonly called aurum paradoxum, alloyed with gold and iron; it exifts alfo in the ore called graphic gold, aurum graphicum, with gold and filver, alloyed with gold and lead; it exifts in the yellow foliated gold ore of Nagyag. Tellurium is of a tin white inclining to yellow. It is the moft fufible and moft volatile of the metals. It is foluble in fulphuric, nitric, and nitro-muriatic acids. The latter folution is decompofable by water: boiling fulphuric acid likewife diffolves it. This folution acquires a fine red colour when fuffered to cool, which vanifhes by heating it. It combines with fulphur.

Tellurium is obtained from its ores by diffolving them in nitro-muriatic acid. The folution is to be decompofed by the addition of potafh, in fuch a manner that the white precipitate which firft appears, becomes rediffolved, and a brown precipitate (which is the gold and iron which was contained in the ore) only remains. On faturating the alcaline folution thus deprived of iron and gold, by the addition of muriatic acid, the oxid of tellurium is precipitated in the form of a white powder. On forming this oxid into a pafte with oil, and heating it in a retort, brilliant metallic drops appear in the upper part of the veffel, which increafe until the reduction is accomplifhed. Thefe are the metal called tellurium.

Uranium exifts in the ftate of an oxid in the ore called pitchblende or oxid of uranium, contaminated with iron or copper. Oxid of uranium, combined with carbonic acid, forms the mineral called chalcolite or green mica. Thefe ores are found in the mines of Saxony.

Uranium

Uranium has hitherto been produced only in ſmall agglutinated metallic globules of a deep grey colour. It is very difficult of fuſion. It is attacked by ſeveral of the acids, unites to phoſphorus, and its oxids are ſoluble in alkalis. It tinges glaſs of a greeniſh yellow. It is obtained from the pitchblende, by depriving the ore of the greateſt part of its ſulphur by torrefaction, effecting a ſolution by means of nitric acid, decompoſing this ſolution by a carbonated alkali, and reducing the oxid thus precipitated by heat, after having formed it into a paſte with oil.

Titanium exiſts in union with iron, mangaueſe, and ſilex, in a blackiſh ſand found at Menachan, in Cornwall, and from hence called menachanite. It has alſo been found united to lime and ſilex in an ore called titanite. This metal has been hitherto obtained in an incoherent agglutinated maſs of a red colour, very brittle and refractory. It is ſoluble in moſt of the acids. It is not combinable with ſulphur. Its oxids are blue, red, and white. It may be procured from the ore called titanite, by fuſing it with potaſh, and diſſolving the alcaline maſs in water: a white precipitate falls down which is the white oxid of titanium. This carbonated oxid formed into a paſte with oil yields metallic titanium by an intenſe heat.

Chrome exiſts in the ſtate of an oxid in red lead ore of Siberia, or chromate of lead. It has alſo been met with in combination with iron and alumine, forming the ore called chromate of iron. The emerald of Peru and Spinel ruby are coloured by the oxids of this metal. It is obtained from the ore called chromate of lead, by fuſing it with car-

bonate of potash, dissolving the mass in water, precipitating the chromic acid, and heating it in a charcoal crucible. Its colour is white. It appears in an agglutinated mass, is very hard, brittle, and very fusible. Its oxids are of a beautiful green. Its acid is of a red or orange colour.

Columbium has been hitherto found only in a peculiar ore, greatly resembling the chromate of iron, found in the Massachusett mines, in North America. It has been examined only in the state of an acid, (columbic acid), which is a white powder. It was discovered 1802, by Mr. Hatchett. For a fuller account the reader may consult Mr. Hatchett's paper in the Phil. Trans. 1802, p. 1. and p. 40; or, Nicholson's Journal, vol. i.

## CHAP. VII.

### SIMPLE OR PRIMITIVE EARTHS.

By the name of earth chemists distinguish those simple bodies, which when in a pure state are concrete, friable, white, and opake substances, whose specific gravity never exceeds 5. They are absolutely uninflammable, and very sparingly soluble in water, but capable of uniting chemically with acids, alcalies, phosphorus, and sulphur, and with each other. Most of them are insipid; few of them are found in a state of purity. They form the rocks, stone, and earthy part of this globe.

Lime

Lime or calcareous earth exiſts, though not in a pure ſtate, in common quick lime. If pounded chalk be ſeveral times boiled in diſtilled water, the remainder will conſiſt of calcareous earth of tolerable purity, united to about an equal weight of carbonic acid. If diſtilled vinegar be added to this powder, it will form a ſaline combination with the earth only, at the ſame time that the carbonic acid, aſſuming an elaſtic form, flies off. To this ſolution, decanted from the impurities, carbonate of ammonia being added, the alkali will unite with the vinegar, while the calcareous earth combines with the carbonic acid of the ammonia, and falls to the bottom. This powder, well waſhed and dried, is lime, or calcareous earth united with carbonic acid. This laſt may be driven off by expoſure to a white heat, and will leave the pure lime diſengaged. Y

Calcareous earth requires about four hundred and eighty times its weight of water to diſſolve it at the temperature of 60°, to which it gives a pungent taſte. This water, called lime-water, acquires a white cruſt on the ſurface, by expoſure to the atmoſphere, which breaks and falls to the bottom, another cruſt forming ſoon after, and ſo on till the whole of the lime is precipitated. The precipitate is chalk, or carbonate of lime; whence the proceſs may be eaſily explained. For carbonate of lime is ſcarcely, if at all, ſoluble in water: and the lime contained in the water being converted into a carbonate, by the acceſſion of carbonic acid from the atmoſphere, becomes an inſoluble cruſt, Z

that falls at intervals, as its quantity becomes too great to be supported at the surface.

A This earth is soluble in most of the acids. It is infusible in every degree of heat yet obtained, except that of the famous lens of PARKER, in London, which produced a slight beginning of fusion. Yet it will melt in a more moderate heat, if mixed with other earths, of which it then appears to be the flux or solvent.

B The specimens of minerals chiefly consisting of calcareous earth are, lime-stone, chalk, marl, gypsum, pearl-spar, marbles, &c. of this earth combined either with carbonic or some other acid. It forms the basis of animal bones and shells.

C Barytes, terra ponderosa, or ponderous earth. The commonest specimens of this earth are the ponderous spar, or sulphate of barytes, so called from its great weight, best known to our English miners by the name of cawk. It is met with opake, white, grey or yellowish, either irregularly shaped, or in a singular form, resembling convex lenses, set edgewise into the mass it adheres to. The transparent specimens are prismical, and of considerable hardness. All these consist of ponderous earth, combined with the sulphuric acid. It is called sulphate of barytes.

D Barytes, combined with carbonic acid, has been found at Anglezark in Lancashire, and elsewhere. It is of a striated texture, and its specific gravity is 4,331.

E If sulphate of barytes be exposed to a strong red heat, for about two hours, with nearly twice its weight

of

of fixed alkali, the acid quits the earth to combine with this last, forming a neutral salt, which may be washed away, and leaves the earth combined with carbonic acid and water. The carbonic acid may be expelled by heat. From the native carbonate it may be obtained, by dissolving this mineral in diluted nitric acid, evaporating the solution and exposing the obtained nitrate of barytes to a red heat.

F Pure barytes, thus obtained, is soluble in about 20 times its weight of cold and twice its weight of boiling water. This water resembles lime-water in taste, and deposits its earth, by exposure to the air, in the same manner. It turns blue vegetables green. It has a stronger affinity than any other body for sulphuric acid. It is caustic to the skin, and is a poison.

G Strontia, or strontian earth, hitherto found only in combination with sulphuric acid and carbonic acid, forming the minerals called sulphate and carbonate of strontia; it may be obtained from them like barytes, by fusion with potash, or by nitric acid. Strontian earth is caustic. It is soluble in 200 times its weight of cold water, and in seven of boiling water; it crystallizes on cooling in rhomboidal crystals, and changes vegetable blues to green; combines with phosphorus and sulphur, is soluble in nitric, muriatic and acetic acids, and the salts formed with them tinge the flame of burning bodies of a carmine red.

H Magnesia, or magnesian earth, enters into the composition of some earthy substances, the chief of which are steatites, serpentines, soap-rock, French chalk, asbestos, and talc. It exists in the sea-water in great quan-

tities, combined either with the muriatic or ſulphuric acids. Sulphate of magneſia, or Epſom ſalt, is a combination of ſulphuric acid with magneſia. If this be diſſolved in water, and carbonate of potaſh added, the magneſia is precipitated in combination with the carbonic acid, while the potaſh unites with the ſulphuric acid. The magneſia thus obtained, contains about one fourth of its weight of carbonic acid, and nearly the ſame quantity of water. Both are driven off by fire, by which the magneſia is rendered pure, and has ſomewhat leſs than half the weight it poſſeſſed in its former mild ſtate. It is inſoluble in water. It very ſlightly changes vegetable blues to green. It forms ſoluble ſalts of a bitter taſte with moſt of the acids. It combines with ſulphur, but not with phoſphorus; becomes phoſphoreſcent when ſtrongly heated, and becomes ignited by the affuſion of denſe acids.

I Alumine, clay, or argillaceous earth, is found every where in great quantities, but in the native ſpecimens it is always mixed with a conſiderable quantity of other earths. Alum is a ſalt, conſiſting of alumine, combined with the ſulphuric acid and a ſmall portion of alkali. If it be diſſolved in water, and carbonate of ammonia be added, this laſt unites with the acid while the earth is precipitated, combined with carbonic acid, from which it may be freed by heat.

K Alumine imbibes water ſtrongly, but is inſoluble therein. When ſufficiently divided, it forms a tenacious maſs with water, ſo as to admit of being moulded into various forms. It contracts very much by heat, and acquires a flinty hardneſs by baking, and does

not then suffer any alteration from water; though its original softness and tenacity may be again restored by solution in acids, and precipitation. It strongly adheres to the tongue. It combines with most of the acids, and forms salts of a sweetish styptic taste. Clays, boles, fullers earth, corundum, &c. are specimens of clay.

This earth, which is so useful in the arts, has been applied *, with great success to the admeasurement of the higher degrees of heat. For as the expansion of the mercury, in a common thermometer, indicates the successive augmentations of temperature, so the contractions of the volume of a small brick of clay, by exposure to ignition, are found to be greater, the more violent the heat. By the help of this property we are in possession of an invaluable method of measuring and comparing those high temperatures. It forms the basis of all earthen-ware and porcelains.

Siliceous earth, or flint, abounds in many substances. Colourless rock crystal is one of the purest specimens. Quartz, flint, granite, cornelian, and all the varieties of opal belong to this class. Extreme hardness is most commonly a characteristic of siliceous earths, so that stones, in which it predominates, will strike fire with steel, or at least will scratch its surface, however highly tempered. They have a vitreous appearance and high polish. They are not acted upon by any acid, the fluoric excepted.

To procure siliceous earth in a pure state, clear

* By J. Wedgwood, Esq. See the Phil. Transf.

cryſtals, or quartz, muſt be heated to redneſs, and quenched in cold water repeatedly to render it brittle, and then reduced into powder, and melted with four times its weight of potaſh. The compound called ſiliceous potaſh is then to be diſſolved in water, and muriatic acid added in exceſs. The alkali and acid unite together, forming a ſalt that remains in ſolution: if there be any other kind of earth preſent, it will likewiſe combine with the ſuperfluous acid. But the ſiliceous earth being diſengaged, falls to the bottom in a ſubtile powder, which muſt be cleared of the ſaline liquor by decantation, and repeated waſhing with water.

This earth is acted on by no acid but the fluoric. Fixed alkalis diſſolve it, either in the dry or moiſt way. Like the other earths, it is not fuſible without addition by any heat yet obtained.

Glucine has been diſcovered only in 3 minerals; namely, in the beril, in the emerald, and in the gadobnete. It forms ſweet or ſaccharine ſalts with alcalies. It is precipitable by all the ſuccinates. It is ſoluble in alcalies and their carbonates. It is procured by fuſing the beril with potaſh, ſeparating the ſilex by muriatic acid, decompoſing the remaining fluid by carbonate of potaſh, rediſſolving the precipitate in ſulphuric acid, and ſeparating the alum formed by cryſtallization. From the remaining fluid the glucine may be precipitated by carbonate of ammonia.

Zircon, or jargon, is found in the two gems, called jargon, and in the hyacinth. It differs from all other earths by forming ſalts with acids which are decom-

poſable

posable by alumine, glucine, the alcalies, and by mere heat. It is very ponderous, and harsh to the touch, void of taste, insoluble in water, but obstinately retaining a large quantity of it, forming a kind of horn, or dry gelly of a vitreous nature. Yttria exists in a fossil called ytterby or gadolinite. It is the heaviest of all the earths, its specifice gravity being 4,842. It is precipitable from acid solutions by prussiate of potash, and by tannin. It is insoluble in water, in alcalies; but soluble in carbonate of ammonia. It differs from glucine by its insolubility in alcalies, and precipitability by succinates.

## CHAP. VIII.

### ALCALIES.

Alcalies are a class of bodies which are commonly defined to be incombustible. Soluble in water, caustic, capable of forming salts with acids, of combining with alcohol, oils, earth, sulphur, and phosphorus, and of changing vegetable blues to green.

Potash. Impure samples of this alcali are met with in commerce, under the names of pearlash, salt of tartar, potash, &c. It was formerly denominated, vegetable alcali, but improperly, because it is abundantly met with in mineral bodies. Dr. Kennedy found it in the pumice stone; professor Klaporth in the leucite; and Mr. Accum has lately discovered it in a siliceous stone found in Cornwall.

Potash

Potaſh was for a long time unknown in its pure ſtate. It is moſt plentifully obtained from vegetable ſubſtances. If vegetable bodies be burned in the open air, and the aſhes be repeatedly waſhed with water, till this fluid paſſes taſteleſs, and if this fluid be evaporated to dryneſs, the ſubſtance which remains is called potaſh; far, however, from being in a ſtate of purity. In this ſtate it is met with in the market. It may be obtained in a pure ſtate, by digeſting it in alcohol, which diſſolves only the pure potaſh, and ſubſequent abſtraction of the alcohol. Pure potaſh is a ſolid white cryſtallizable ſubſtance; it is highly cauſtic, deliqueſcent, ſoluble in half its weight of water, perfectly incombuſtible, combining with all the acids, oils, ſulphur, and moſt of the earths.

Soda greatly reſembles potaſh. Like potaſh, it is procured by lixiviation from the aſhes of burned vegetables; but only from thoſe which grow upon the ſea ſhore. It occurs in the mineral kingdom united to ſulphuric, muriatic, boracic, and carbonic acids. It is generally prepared in the large way, by decompoſing ſulphate of ſoda by carbonate of potaſh *. It differs particularly from potaſh by the following properties: In the fire it is rather more fuſible; when expoſed to the contact of air it attracts moiſture and carbonic acid, but it does not liquefy like potaſh; it merely acquires a paſty conſiſtence, and at laſt crumbles into powder. It is not altered by light. It adheres leſs ſtrongly to

* See Mr. Accum's paper on the manufacturing of Soda, in Nicholſon's Journal of Natural Philoſophy, &c.

the

the acids. It fuſes and diſſolves alumine more eaſily.

The combination of potaſh, or ſoda, with ſilex includes the manufacture of glaſs. Glaſs is compoſed of about equal parts of potaſh or ſoda and ſilex or flint. It is harder and more durable in proportion to the exceſs of the ſilex. The tranſparency of glaſs depends upon its being cooled quickly; for if ſuffered to cool very ſlowly, it aſſumes a radiated cryſtalline appearance, and becomes perfectly opake.

The combination of alcalies with oils, conſtitutes the formation of ſoap. The art of making ſoap conſiſts in depriving the alcali of the carbonic acid it may be combined with, and afterwards combining it with ſome oily ſubſtance, which, in the manufactories, is done by gentle boiling. One part of quicklime, and two of ſoda, are boiled together for a ſhort time, with twelve parts of water. The filtered lixivium is ſoap-lye, or a ſolution of cauſtic alcali, and may be concentrated by heat. If it be concentrated till its ſpecific gravity is about 1.375, or, which is the ſame thing, till a phial that can contain an ounce of water will hold one ounce ſeven penny-weights and a half of the lye, the ſoap may be made without boiling. One part of this lye muſt be mixed with two of olive-oil in a glaſs or ſtone-ware veſſel. The mixture being ſtirred from time to time with a wooden ſpatula ſoon becomes thick and white, and in ſeven or eight days the combination is completed, and forms a very white and firm ſoap.

The lye in large manufactories is made no ſtronger than

than to float a new-laid egg, when the workmen begin to form the mixture. To a part of the lye diluted they add an equal weight of oil, which is set on a gentle fire, and agitated. When the mixture begins to unite, the rest of the lye is added, and the whole digested by a gentle heat till the soap is formed. If it be well made it is firm and white, not subject to become moist by exposure to the air, and completely mixes with water, without exhibiting any drops of oil on the surface. Trial is made of it, and the requisite alterations are obtained by the addition either of oil or alcali. At the end of the boiling common salt is thrown in. A twofold effect is hereby produced. The soap is separated, because not diffusible in salt-water; and it is rendered harder by the complete separation of vegetable alcali from it: for the vegetable alcali does not make a firm soap; and, as much of it as may be in the mixture, decomposes a portion of the common salt by stronger affinity to its acid. The alcali of the decomposed common salt, namely, the mineral, unites therefore with that portion of the oil which would otherwise have remained in combination with the vegetable alcali.

The cleansing property of soap is well known, and is to be attributed to its alcali, which will render a small portion of oily matter, beyond what it is already united to, diffusible in water. Soap is easily prevented from mixing with water by any salt, except alcalis, and is therefore no contemptible test of the purity of natural waters (149, o).

CHAP.

# CHAP. IX.

## GASES, OR AERIFORM FLUIDS.

Experiments to be made with the various kinds of gafes, or airs, require an apparatus of veffels proper for confining it. The chief are thofe we are about to defcribe.

Fig. 171, is a tub for containing water. In this tub is fixed a fhelf, fo placed that it may be about an inch below the furface of the water, when the tub is nearly full. *a* is a cylindrical glafs jar, *b* is a bottle, into the neck of which the bent tube is fitted, by grinding. Suppofe, now, that the veffel *a* be plunged in the water, fo as to be filled, and afterwards raifed, with its mouth downwards, and placed on the fhelf, it will continue full of water on the principle of the barometer: if its rim be made to overhang the edge of the fhelf, it will be eafy to introduce the end of the tube of the bottle beneath it; and if the veffel *b* contain fuch matters as by their action on each other afford gas, that gas will pafs through the tube, and rife to the top of *a*, expelling more or lefs of the water. A candle may be applied beneath *b*, in cafes where heat is wanted.

Air or gas may be transferred from one veffel to another by the help of a glafs-funnel under water. Thus if the veffel *a* being fuppofed to be previoufly filled with water,

water, and placed on the ſhelf, over a hole in which a funnel is ſtuck, the gas may be poured out of any other veſſel through the funnel into A.

Many kinds of gas combine with water, and therefore require to be treated in an apparatus in which quickſilver is made uſe of. This fluid being very ponderous, and of conſiderable price, motives both of convenience and œconomy require that the apparatus ſhould be made ſmaller than when water is uſed.

Fig. 166, is an improved pneumatic mercurial trough. It conſiſts of a mahogany box of greater or leſs ſize, ſtanding in a tray made of the ſame wood. The principal parts of this apparatus are, the ſhelves of the trough and the bottom. The reſervoir properly ſo called, is the interval between theſe two planes. The advantage of this apparatus conſiſts in having a broad ſolid ſhelf on one ſide of the trough, and a narrow ſliding ſhelf, with a hole in the centre, which communicates with a funnel ſhaped opening on the ſide of the large ſhelf. Veſſels placed on the ſliding ſhelf may be conveniently filled with gas, by directing the conveying tube of a gas bottle, or the neck of a retort into this excavation, and then ſliding it on the large ſhelf of the apparatus, which, from being on one ſide the trough, enables the operator to perform his experiments with a leſs quantity of mercury, and in an eaſier manner than in the troughs of the uſual conſtruction. The tray A is uſeful for collecting the mercury which may be ſpilled.

Fig. 167,

Fig. 167, is a detonating or eudiometer tube of P
glaſs. Its bore is about $\frac{1}{2}$ inch, and its height 18. It is graduated into cubic inches, and ſubdivided into decimal parts. By means of the two conductors A, A, a quantity of gas, confined in the tube by water or mercury, may eaſily be inflamed by the electric ſpark. Hence this tube is extremely convenient for ſhowing the production of water and nitrous acid, by detonating oxigen and hydrogen, or oxigen and nitrogen.

Fig. 168, is a flaſk for weighing gaſes. Its orifice Q
is furniſhed with a ſtop-cock *a*. The flaſk is to be exhauſted by means of an air-pump, and then connected with a bell glaſs filled with air, and provided with a ſtop-cock. By opening both the ſtop cocks, the gas contained in the bell-glaſs may be transferred into the flaſk, on preſſing down the bell-glaſs into the water of the pneumatic trough; the gas will then be forced up into the flaſk. The ſtop-cocks being then ſhut, the flaſk may be removed, and its weight aſcertained. The difference between the weights of the flaſk when exhauſted, and when filled, give the weight of the gas in the flaſk, which may, by the ſame method, be compared to that of common air.

Fig. 169, is a perſpective view of an improved R
gaſometer. It conſiſts of an exterior cylindrical veſſel *a*, made of japanned iron or copper; and an internal glaſs cylindrical veſſel *b*. The japanned veſſel is furniſhed with two ſtop-cocks, one of which is fixed at the upper part, and the other at the bottom on oppoſite ſides of the veſſels. From the upper cock a tube *cc* runs down the outſide of the veſſel *a*, croſſing its bottom to the ſtop-cock *f*. In the centre of the veſſel

this tube branches upwards through the bottom of the vessel *a*, and thus a communication is made with the stop-cock and the interior glass vessel *b*, which is suspended in the exterior vessel *a*, by means of weights and pullies contained in the bent tube *d d*. A graduated rod, affixed by means of a cap, to the vessel *b*, expresses by the coincidence of any of its divisions with the aperture *x*, the capacity of the emerged part of the glass vessel, and therefore measures the quantity of gas contained in it. In using this apparatus, the vessel *a* is filled with water up to the aperture of the tube in the centre of the vessel. The glass vessel *b* is then depressed, till the coincidence of the zero point of the graduated rod with the aperture *x*, indicates its total immersion. This being done, a communication is made between the tube *c c*, and the apparatus from which the gas proceeds, by opening either of the cocks, and keeping the other shut. The gas thus introduced will, of course, pass through the tube *c c*, and enter the vessel *b*, which as it becomes filled will emerge by the pressure of the gas. For breathing or transferring gases from this apparatus, a flexible tube *e* may be joined to either of the stop-cocks, and the quantity of gas expended will be measured by the graduated tube *g*.

Fig. 170, is an improved gas-holder, very useful for the combustion of different substances in oxigen gas, and for other purposes. It consists of a cylindrical vessel, having a small cistern at the top, which is connected with the gas-holder by means of two tubes furnished with stop-cocks. The cylindrical vessel has also

alſo a braſs ſtop-cock on the ſide, and a glaſs gage, or regiſter tube, ſhowing the quantity of included gas by the levels of the water. The following is a deſcription of the different parts.

The gas-holder, fig. 170, *g*, may contain from two to ten gallons.

P, the regiſter tube, the ends of which are cemented into two tin ſockets by corks at the top and the bottom of the gas-holder, into which it opens at both ends: of courſe the level of the water in the apparatus will always be ſeen in the tube, and conſequently that of the gas.

C, the circular ciſtern, with its two cocks and pipes, marked 1 and 2.

*c* K, a braſs cock on the ſide, with a ſcrew, to which bladders or a blowpipe may be attached.

*o*, an opening into the gas-holder, in which a pipe is ſoldered at ſuch an angle, that when all the uppermoſt cocks are ſhut no water can poſſibly eſcape. But when a conducting pipe, from a retort or other apparatus generating gas, is introduced into this opening, then, as the gas paſſes up into the gas-holder, an equal quantity of water will be diſcharged at *o* into any veſſel fit to receive it.

S, a ſpout on the ſide of the ciſtern to enable the operator to add water even when the receiver fills its whole area.

*b b*, handles to lift the gas-holder by.

R, a glaſs deflagrating receiver ſtanding in the ciſtern.

*a*, its adopting cork and cock.

*d*, a deflagrating diſh of iron for ſulphur, phoſphorus, charcoal, ſugar, camphor, &c.

To make uſe of this apparatus, firſt fill the gas-holder with water, by cloſing the opening *o* with a cork, and alſo the cock *c* K, and keeping the circular ciſtern full of water, while the cocks 1 and 2 are both open. The air is driven out of the gas-holder through the cock 1, by the water deſcending into it by the cock 2. When full, the water in the regiſter will be on a level with the top of the gas-holder. Then ſhut the cocks 1 and 2. You may now remove the cork from the opening *o*, which is then prepared to receive the conducting-pipe from any apparatus from which the gas is generating. As the gas is delivered the water eſcapes, and ſhould be caught in any convenient veſſel. The regiſter will then ſhow the quantity received: when full, cloſe the opening *o* with a cork wrapped in leather, which prevents the communication with the atmoſphere. It may now be eaſily removed or conveyed where it is wanted.

When it is required to fill a glaſs receiver, as R with the gas, having previouſly filled the circular ciſtern with water, place it in the ciſtern, put in the adopting cock *a*, and, with the mouth applied to the cock, exhauſt the receiver, in which the water will riſe till full. Then cloſe the cock *a*, and open the two cocks 1 and 2, and the gas will aſcend into the receiver, while the water will take its place in the gas-holder. The ſubſtances to be experimented upon

ſhould

ſhould be placed in the deflagrating pan *d*, in which they are intended to be expoſed to the action of the gas by being in part ignited.

When the blow-pipe is uſed it ſhould be ſcrewed on to the cock *c* K; the ciſtern ſhould be kept full by reverſing a large receiver of water over it, or any other ſimple method, and the cock 2 only opened for the admiſſion of water.

Bladders mounted with cocks may be filled with a gas by firſt emptying them of atmoſpheric air, then ſcrewing them to the cock *c K*, filling the ciſtern with water, and opening the cock 2. In all theſe inſtances the quantity uſed may be aſcertained from the regiſter, which has a ſcale of pints or cubic inches attached to it.

Oxigen gas is an elaſtic inviſible fluid. Its ſpecific v gravity is 0,00135. It ſupports combuſtion, is neceſſary for reſpiration and vegetation and is abſorbed in theſe proceſſes. It is conſidered as the cauſe of acidity, and from this property is derived its name, a word denoting the origin of acidity. It conſtitutes 0,21 parts of atmoſpheric air, and is a conſtituent part of water. It may be obtained in a very pure ſtate by heating oxigenated muriate of potaſh in a retort to redneſs, and collecting the gas over water; or in a more economical manner, by heating black oxid of manganeſe to a red heat in an iron retort.

Nitrogen or azotic gas, conſtitutes 0,79 of the at- w moſphere. It is unable to ſupport reſpiration, combuſtion, or vegetation, and is not decompoſed in theſe proceſſes. It forms a conſtituent part of nitric acid,

and of ammonia. It may be obtained from freſh animal ſubſtances, by merely heating them in a retort with weak nitric acid. Or by making a quantity of ſulphuret of potaſh or iron into a paſte with water, and expoſing this mixture to a confined quantity of atmoſpheric air. The oxigen of the air will be abſorbed by the moiſtened ſulphuret, and the reſiduary elaſtic fluid will be nitrogen.

x Atmoſpheric air conſiſts of 21 parts of oxigen gas, and 79 nitrogen. Its ſpecific gravity is 0,00123. Its component parts ſeem not to be chemically combined. It contains in ſolution, beſides the gaſes now deſcribed, water and carbonic acid.

y Gazeous oxid of nitrogen, is a gas containing 0,37 of oxigen. Water abſorbs about half its weight of it. It ſupports combuſtion. It has a diſtinct and ſweet taſte. It explodes with hydrogen. Animals, when wholly confined in it, ſoon become reſtleſs and die. When mingled with atmoſpheric air, and then received into the lungs, it generates highly pleaſurable ſenſations. Gazeous oxid of nitrogen may be obtained by heating nitrate of ammonia in a retort, and receiving the gas over water in the uſual manner.

z Nitrous gas. This gas is exceedingly hurtful to animals. The greateſt number of combuſtible bodies refuſe to burn in it. When mixed with about $\frac{2}{5}$ of oxigen gas it produces red fumes (nitrous acid) which are combined with water. Phoſphorus does not ſhine in it. It is compoſed of 56 of oxigen gas, and 44 nitrogen. Nitrous gas may be obtained by cauſing nitric

nitric acid to act upon copper, silver, zinc, or mercury, and receiving the gas from the retort over water.

Hydrogen gas. This gas is found collected in mines A and caverns. It is the lightest body with which we are acquainted. It is highly inflammable in contact with oxigen gas or with atmospheric air, and detonates on the application of a burning body when mixed with them. It extinguishes flame, and is hurtful to animal life. It dissolves phosphorus, sulphur, charcoal, arsenic, zinc, &c., forming with them peculiar gases. It may be obtained by pouring dilute sulphuric acid upon iron filings or zinc, and collecting the gas over water.

Hydrogen combined with oxigen in the proportion B of 14, 42 to 85, 58, forms water. Water exists at $32^\circ$ in a solid form, and is crystallized. At $212^\circ$ it expands to 2000 times its bulk, and is converted into a very elastic vapour. It is the only binary combination of hydrogen and oxigen.

Hydrogen combined with nitrogen, in the propor- C tion of one part of the former with four of the latter, forms ammonia. It exists in its purest form in a gaseous state called ammoniacal gas. It has an urinous and acrid odour, irritating the nostrils and eyes, and an acrid and caustic taste. It is not respirable, extinguishes flame, changes vegetable blues to green, and is decomposed by being passed through a red hot tube, and by the electric spark, into its component parts. It combines with all the acids and forms neutral salts. It is generally classed among the alcalies. Ammonia is produced by mingling equal parts of lime and muriate of ammonia, heating the mixture in a retort, and col-

lecting the gas over mercury in the mercurial apparatus.

D Carbonic acid gas. This gas extinguishes flame. It is fatal to animal life. Its taste is pungent and acid. It unites with water, and communicates to it a sparkling property and pungent acidulous taste. It is rapidly condensed by alcalies. Its specific weight to that of atmospheric air is as 1500 to 1000. It may be poured out of one vessel into another. Carbonic acid gas may be obtained by exposing marble, or lime-stone to a red heat, or by affusing upon it dilute sulphuric, nitric, or muriatic acids. It is likewise produced during fermentation, and by burning diamond or charcoal in oxigen gas.

E Gazeous oxid of carbon. This gas consists of 25,89 carbon, and 74,11 oxigen. It does not support flame or respiration. It burns with oxigen, and is converted into carbonic acid. It may be obtained by exposing to a red heat, a mixture of chalk and filings of zinc, or black oxid of iron, and charcoal powder. The gases called heavy and light carbonated hydrogen, differ from this merely in the proportion of their ingredients.

F Sulphuretted hydrogen gas is a compound of 71 of sulphur and 29 of hydrogen. It has the odour of putrid eggs. Is not respirable, burns with oxigen gas without explosion, and deposits sulphur. It is absorbable by water, and reddens vegetable blues. It may be procured by pouring a dilute acid upon a moistened alcaline sulphuret.

Phospho-

Phosphorated hydrogen gas. This gas is the most inflammable substance in nature. It is particularly distinguished from all other gases by the property of taking fire immediately when brought into contact with atmospheric air. Mixed with oxigen gas it burns with great violence. It is partly absorbable by water. It may be procured by heating in a retort one part of phosphorus with two of potash or soda, and six of water. G

## CHAP. X.

### SIMPLE, OR UNDECOMPOSABLE ACIDS; AND ACIDS COMPOSED OF TWO BASES.

ACIDS, in the language of chemists, are those substances which are distinguished by the following properties: Their taste is sour; they change vegetable blues red; they unite to water without suffering any change except what depends on solution; they unite to alcalies, earths, and metallic oxids, and form with them compounds, possessing new properties, called salts. H

Sulphuric acid is composed of sulphur and oxigen. I
It is also called vitriolic acid, because it was formerly prepared from the salt, vulgarly called vitriol. It is usually obtained by combustion of sulphur. Sulphur is either found native in the neighbourhood of volcanoes, or united with earths or metals. One of the J
most common sulphureous compounds is the pyrites, or mundic. This consists usually of sulphur, iron,

clay,

clay, and ſiliceous earth. It is generally of a yellow or greyiſh colour, of a globular or cubic ſhape, internally radiated, or ſometimes lamellar. With the ſteel it ſtrikes fire plentifully, whence its name is derived. If pyrites be expoſed to heat in cloſed veſſels, the ſulphur ſublimes; but in the open air it is decompoſed by combuſtion, the quantity and combination of the principles left in the maſs being by that means changed.

K Pyrites, by long expoſure to the action of the air and moiſture, ſuffers a remarkable change in its component parts. The ſulphur, by a ſlow proceſs analogous to combuſtion, becomes acidified, attracts water, and unites with the iron, forming ſulphate of iron, or vitriol, and with the clay, forming alum. Theſe may be obtained by ſolution in water; and a ſubſequent evaporation diminiſhes the quantity of the ſolvent, ſo as to cauſe the ſalts to ſeparate in the form of cryſtals.

L If ſulphate of iron be expoſed to diſtillation, the water that entered into the compoſition of the cryſtals riſes, and afterwards the greateſt part of the acid, with ſome exceſs of ſulphur combined with it, leaving a brown maſs in the retort, called red oxid of iron, or colcothar.

M This proceſs for obtaining the vitriolic acid is not now uſed, becauſe a cheaper method has been contrived for procuring it immediately from ſulphur. A quantity of ſulphur and nitre groſsly mixed, are placed in a veſſel within a ſmall chamber or room, lined with lead, and containing ſome few inches of

water

water on its bottom. The ſulphur is lighted, and the room cloſed. The nitre ſerves to maintain the combuſtion, by ſupplying oxigen, and the ſulphuric acid is thus formed, and combines with the water. To expedite this combination, it is ſaid that ſteam of water is introduced into the cloſed room during the combuſtion. By a repetition of the proceſs, the water becomes more and more acid. And the acid is then concentrated by diſtilling off the ſuperfluous water.

Sulphuric acid is denſe, colourleſs, and has a ſtronger tendency to combination in moſt caſes than every other acid. It may be ſo far deprived of water as to become concrete, but it attracts this fluid ſo powerfully as to deliqueſce by expoſure to the atmoſphere in a ſhort time, and does not ceaſe to attract the humidity of the air till it has acquired more than ſix times its original weight. In caſes where a certain quantity of air is required to be diveſted of its moiſture, it may be performed by placing a cup, containing concentrated ſulphuric acid, under the receiver that confines the air.

Sulphuric acid has a ſpecific gravity of 1.85. It has a ſtrong acid taſte. It is decompoſed by moſt of the inflammable ſubſtances. It has no action upon platina, gold, tungſten, and titanium. It decompoſes the alcaline and earthy ſulphurets, and reduces all organic matters to charcoal. It contains 56 ſulphur and 44 oxigen. The combination of this acid with different baſes forms the ſalts called ſulphates.

If

P If ſulphuric acid be poured into a ſolution of potaſh, to ſaturation, which may be determined by a ſmall quantity of the liquid producing no change of colour with the tincture of litmus, a neutral ſalt is formed that aſſumes the figure of cryſtals, as the water is diminiſhed by evaporation. This is called ſulphate of potaſh, vitriolated vegetable alcali, or vitriolated tartar, and contains 31 parts of acid, 63 of alcali, and 6 of water. It is not eaſy of ſolution in water, requiring 16 times its weight to diſſolve it in the temperature of 60°; but if the water be boiling, 5 parts are ſufficient.

Q Sulphate of ſoda, or Glauber's ſalt, may be produced in the ſame manner, by making uſe of the mineral alcali inſtead of the vegetable. It contains 14 parts of acid, 22 of alcali, and 64 of water, and reſembles ſulphate of potaſh in many of its properties, but requires only 3 times its weight of water to diſſolve it at the temperature of 60°. Great part of the water that enters into the formation of the cryſtals is diſſipated by expoſure for ſome time to the air, the ſalt gradually falling into a white powder or efflореſcence.

R Sulphate of ammonia contains 42 parts acid, 40 of alcali, and 18 of water.

S Sulphate of lime, commonly called ſelenite, abounds in vaſt quantities in nature, and accordingly as its external appearance and texture differs, it is called gypſum, lapis ſpecularis, alabaſter. In the temperature of 60° it requires about 500 times its weight of water to diſſolve it, and thence was formerly reckoned

among

among the earths, though its component parts are 30 acid, 32 earth, and 38 water. By expoſure to heat a little below ignition, about 20 parts of its water are diſſipated, at the ſame time that it falls into a powder, which is agitated by the vapours that eſcape in ſuch a manner as to cauſe the appearance of boiling. This powder is known in commerce by the name of plaſter of Paris, and is chiefly uſed for making ſtatues, and other articles that receive their figure from a mould; an uſe to which it is admirably adapted, by the ſpeedy reſumption of a ſolid form, when the water of cryſtallization is reſtored: for, if the powder be mixed with water, to the conſiſtence of thin paſte, it may be poured into a mould, and will run into all the ſtrokes and cavities with the greateſt facility; a few minutes after which, the water that maintained the ſtate of fluidity, by mere mixture with the powder, combines intimately with it, and the whole maſs becomes ſolid.

Sulphate of barytes contains 84 parts of barytes, T
13 of acid, and 3 of water; in the native ſpecimens it is inſoluble, or nearly ſo in water.

Sulphate of magneſia, or Epſom ſalt, contains 24 U
parts of acid, 19 of earth, and 57 of water. It effloreſces like Glauber's ſalt, by expoſure to the air, and requires about its own weight of water to diſſolve it in the temperature of 60°.

Sulphate of clay, or alumine, contains 24 parts of V
acid, 18 of earth, and 58 of water, and a little potaſh. Its cryſtals are uſually covered with a ſlight eſfloreſcence. In about 15 times its weight of water, at the

temperature

temperature of 60°, it is totally diſſolved; but at higher degrees of heat it is ſoluble in a very ſmall quantity of that fluid. It is fuſed even by its own water of cryſtallization, and boils up into a frothy maſs, which gradually dries into a white friable ſubſtance, called burnt alum. The alum is, however, no otherwiſe changed than by the loſs of its water, and may be reduced again into its original form by reſtoring it.

w The combination of ſulphur with an alcali may be made either in the dry way, by melting the two ſubſtances together; or in the moiſt way, by boiling ſulphur in an alcaline lixivium, and evaporating the water. This laſt method is, however, ſeldom made uſe of. The ſulphuret has a fetid ſmell, is ſoluble in water, and is very deliqueſcent.

x The combination of ſulphur and alcali attracts water from the atmoſphere, which it decompoſes, together with the water.

y Sulphate of iron, or martial vitriol, known vulgarly by the name of green copperas, contains, when recently cryſtallized, 20 parts of acid, 25 of iron, and 55 of water; but it effloreſces by the loſs of part of its water when expoſed to the air. It requires 6 times its weight of water to diſſolve it in the temperature of 60°. This ſalt is uſed in dying blacks, and in making ink for writing.

z Sulphate of copper, or blue vitriol; of this 30 parts in the 100 are acid, 27 copper, and 43 water. It is uſually obtained from waters in Hungary, Sweden, or Britain, in which it is naturally diſſolved. It requires

about

about 4 times its weight of water to dissolve it in the temperature of 60°. In some places the waters na- A turally containing this salt are made to deposit the copper by exposing pieces of iron to their action. For the acid quits the copper, and forms sulphate of iron, by uniting with the iron, which receives the necessary portion of oxigen from the oxide of copper, which consequently resumes its metallic state. The sulphate of iron being soluble, remains in the water, while the copper falls to the bottom in a muddy or powdery form. If the solution, or water containing sulphate of copper, has no considerable excess of acid, 80 parts of iron will precipitate 100 of copper. One of the tests of the presence of sulphate of copper in a liquid consists in dipping a piece of clean bright iron therein, which becomes immediately covered with a thin coat of copper, in consequence of the beginning of the process of transferring the acid from one metal to the other.

Sulphate of zinc, vulgarly called white vitriol, is of B a white colour, and contains 22 parts of acid, 20 of zinc, and 58 of water. It is soluble in about twice its weight of water at the temperature of 60°.

Sulphureous acid, is a permanently elastic aeriform C fluid; when condensed by water, it is called sulphureous acid. It has a strong suffocating odour. It is in the gazeous state deleterious when inspired. It consists of 8 sulphur and 13 oxigen. Its combination with different bases constitutes the salts called sulphates.

Nitric

D Nitric acid conſiſts of oxigen combined with nitrogen. It is liquid, colourleſs, and tranſparent. It is very corroſive, and tinges the ſkin yellow. It is decompoſed by many ſubſtances. Light converts it in part into nitrous acid. It acts on all the metals, platina, gold, and titanium excepted; and when concentrated ſets fire to oils. It may be obtained by pouring upon two parts of nitrate of potaſh, introduced into a retort, one part of ſulphuric acid, and diſtilling the mixture.

E Nitrous acid differs from nitric acid merely in containing nitrous gas in a ſtate of looſe combination.

F Muriatic acid is a permanently elaſtic aeriform fluid. It deſtroys life, and extinguiſhes flame. It is abſorbable by water, and conſtitutes with it liquid muriatic acid. When pure it is perfectly colourleſs. It emits copious white fumes in a moiſt atmoſphere. It is unalterable by any known combuſtible body. Its combination with earthy, alcaline, or metallic bodies, forms ſalts called muriates.

G Oxigenized muriatic acid is, likewiſe, a permanent aeriform fluid. It is compoſed of 84 muriatic acid and 16 oxigen. It is of a yellow colour both when in a gazeous and in a liquid ſtate, of a very pungent odour and acrid taſte. It ſupports flame; but is abſolutely fatal when introduced into the lungs. It bleaches or deſtroys vegetable colours. It is decompoſable by light. Oxigenized muriatic acid may be produced by cauſing muriatic acid of commerce to act upon black oxid of mangancſe in a retort, and receiving the gas in water.

The union of oxigenized muriatic acid with different H
bases, forms the salts called oxigenized muriates. They are remarkable for inflaming combustible bodies by mere friction and with detonation.

Nitro-muriatic acid is a mixture of the nitric and I
muriatic acids, or of the nitric acid with common salt, or muriate of ammonia. It is vulgarly called aqua regia, from its property of dissolving gold. The power of this solvent on gold consists in the muriatic acid becoming supplied with oxigen from the nitric acid.

Fluoric acid is an invisible elastic aeriform fluid. It J
has a pungent suffocating odour, is heavier than air, and remarkable by the property of dissolving glass or silex. It is combinable with water, and then constitutes liquid fluoric acid. It exists in nature combined with lime, and forms fluate of lime, fluor, or Derbyshire spar. This spar is either transparent or opake, of dif- K
ferent colours, and generally has a cubic, rhomboidal, or polygonal figure. Most specimens, especially the coloured, have the property of becoming phosphorescent, or emitting light, when heated far below ignition, as may be done by laying them on a hot iron; but they lose this property by being made red hot. It does not strike fire with steel. The calcareous earth is fifty-seven parts in the hundred, and the rest fluoric acid and water.

If an equal weight of concentrated sulphuric acid be L
poured on pulverized fluate of lime, in a retort made of lead, a decomposition of the fluate takes place with heat. The sulphuric acid seizes the lime, and the fluoric acid escapes in the form of gas, which may be

confined by mercury, but unites with water in very considerable quantity. If the acid be wanted in a fluid state, it is necessary to adapt a receiver, containing water, about five or six times the weight of the spar. This acid, especially when heated, and in the aerial form, dissolves, and retains siliceous earth, which it takes from the glass-vessels during the distillation, soon corroding them through, if they be not very thick. The fluor acid gas deposits some of this earth by cooling; and the greatest part in the form of a white crust on the surface of water, when it combines with that fluid. In order to obtain the acid free from siliceous earth, it is therefore necessary to use leaden vessels.

M The saline combinations formed by uniting this acid with alcalis, earths, or metallic oxids, are called fluates.

N Boracic acid exists in the form of small shining, laminated crystals. It is fixed and vitrifiable in the fire. Soluble in water and alcohol, to the latter it imparts the property of burning with a green flame. It exists united to soda in the salt called borax. United to lime it forms the mineral called borate of lime. Boracic acid may be procured by dropping into a solution of borate of soda, sulphuric acid, till the solution be rather more than saturated. On evaporating the fluid white scales will be deposited, which when collected, redissolved, and dried, are boracic acid.

O If borax be dissolved to saturation in water, and the sulphuric acid be added, this last will combine with the alcali, and disengage the sedative salt, which will swim at the surface, in the form of white scales. The

filtered

filtered liquor will yield sulphate of soda, or Glauber's salt. This acid is also obtained by sublimation; the alcaline base being separated by the previous addition of some stronger acid.

The acid of borax requires fifty times its weight P of water to hold it in solution. Its acid properties when uncombined are but weakly manifested.

The component parts of purified borax are, 17 Q parts of soda, 34 of a peculiar acid called the acid of borax, or sedative salt, and 47 of water. In this combination not more than about 5 parts of the alcali are really saturated, for which reason borax in many cases acts as an alcali.

Phosphoreous acid is a colourless fluid of an oily ap- R pearance. It has a fetid odour and disagreeable taste, emits thick white fumes, and vivid flame when strongly heated, and is decomposed by charcoal. The proportions of phosphorus and oxigen, of which it consists, are not yet determined. It forms salts called phosphates. Phosphoreous acid may be obtained, by placing sticks of solid phosphorus in a glass funnel, inserted in the neck of a bottle containing water. A piece of glass tube, inserted in the neck of the funnel, will prevent the sticks from falling through. In this situation, if the temperature be moderately warm, the phosphorus will be gradually oxigenized by slow combustion.

Phosphoric acid is composed of 100 parts phospho- S rus, and 154 oxigen. It is crystallizable, fusible, and vitrifiable. It rapidly attracts moisture from the atmosphere, and becomes heated when mingled with

water. It is decompoſed at high temperatures by carbon, and by ſeveral metals. It forms ſalts called phoſphites. Phoſphoric acid is found in great abundance in nature, combined with lime, forming the bones of animals. It alſo exiſts united to oxides of metals.

T If the bones of animals be burned in the fire till they have become white, they are in a proper ſtate to afford the phoſphoric acid. Three parts by weight of this matter in powder may be gradually added to two parts of concentrated ſulphuric acid, and afterwards about five parts of water. This mixture muſt be left to digeſt for a day, water being added occaſionally to ſupply what evaporates; at the end of which time more water muſt be plentifully added, and the liquor ſtrained through a fine ſieve. What remains in the ſieve is gypſum, or ſulphate of lime. The liquor, by evaporation to dryneſs, leaves a reſidue, conſiſting in a great meaſure of the phoſphoric acid, which has been diſengaged from its baſe by the ſulphuric acid. This reſidue, urged by a ſtrong heat, flows into a kind of glaſs of a whitiſh ſemiopake appearance called glacial acid of phoſphorus.

U Arſenious acid conſiſts of 93 parts of arſenic and 7 of oxigen. It is not cryſtallizable, and is very fixed in the fire. It is decompoſable by all combuſtible bodies and by many oxids. It has a ſharp acrid taſte and an alliaceous odour. It is called in commerce white arſenic. It is chiefly procured from arſenical ores of cobalt by ſublimation.

V Arſenic acid attracts moiſture from the atmoſphere,

and is ſoluble in $\frac{2}{3}$ its weight of water: by a red heat it loſes part of its oxigen and becomes converted into arſenious acid; it conſiſts of 91 of arſenic, and 9 of oxigen. It may be obtained by cauſing nitric or nitro-muriatic acid to act by heat on arſenious acid repeatedly, and ſubſequent abſtraction of the acid.

Molybdic acid is a yellowiſh white powder, of an w
acid and metallic taſte. It remains fixed during an intenſe heat as long as the crucible is covered, but the moment it is uncovered, the acid riſes unaltered in white fumes. It is ſoluble in about 600 parts of water. Paper dipt into this ſolution becomes blue when expoſed to vivid light. It forms a blue ſolution with ſulphuric acid. Molybdic acid may be obtained by detonating molybdena in a red heat with nitrate of potaſh and ſubſequent ſolution. Or, by diſtilling nitric acid repeatedly over native molybdena, and waſhing the reſiduary molybdic acid with water to free it from any adhering acid.

Chromic acid exiſts combined with oxid of lead, in x
the red lead ore called chromate of lead; it is alſo found united to iron, forming the native chromate of iron. Chromic acid is of a ruby red colour, of a ſharp metallic taſte, ſoluble in water, decompoſable by heat, and reducible by charcoal. It may be obtained by fuſing the chromate of lead with carbonate of potaſh, and decompoſing the ſolution by nitric acid.

Columbic acid exiſts in the new diſcovered ore y
called columbate of iron. It is a white powder, ſoluble in boiling ſulphuric and muriatic acids, and precipi-

table by water, potaſh, and ſoda. It forms an olive-green precipitate with pruſſiate of potaſh. It unites to potaſh and ſoda, but not with ammonia.

# CHAP. XI.

## ACIDS COMPOSED OF MORE THAN TWO BASES.

z ACETOUS acid is a tranſparent and colourleſs fluid, of an acid taſte, and peculiar pleaſant odour. It is convertible into vapour at about 212°, and combinable with water in every proportion. It acts on almoſt all the metallic ſubſtances. It diſſolves boracic acid, and abſorbs carbonic acid-gas. It is formed by the fermentation of wine, on which account it is called vinegar. However wine is not indiſpenſably neceſſary for its production, as it is found in the urine of animals. The acetous acid produced in fermentation is, however, far from being pure acetous acid, but may be obtained by diſtillation. For this purpoſe the ſtrongeſt vinegar ſhould be carefully diſtilled in a retort.

A Acetic acid is acetous acid deprived of part of its carbon. It has a more pungent ſmell than acetous acid. Its odour is ſo penetrating that when concentrated it is inſupportable. It bliſters and reddens the ſkin. It may be obtained by diſtilling acetate of potaſh with ſulphuric acid, or by ſtrongly heating in a retort metallic acetates.

Oxalic acid is always concrete. It is particularly B diſtinguiſhed by its ſtrong attraction for lime. It acts upon moſt of the metals. It contains more oxigen than any other vegetable acid; and is ſoluble in alcohol, in muriatic and acetous acids. It may be obtained by boiling gently one part of ſugar with five or ſix of nitric acid, and evaporating the ſolution to cryſtallization.

Tartareous acid exiſts in the juice of many vege- C tables, generally combined with lime. It appears in the form of tabular cryſtals. Its taſte is exceedingly ſour. It is not altered by the air. It readily diſſolves in water. It takes lime from the nitric, muriatic, phoſphoric, and acetous acids. It has a ſtrong tendency to unite to potaſh. In one proportion it forms a ſoluble ſalt, (tartrite of potaſh), but when the acid is in exceſs it forms a ſalt of difficult ſolubility, (acidulous tartrite of potaſh). From this property the preſence of tartareous acid in any ſolution may eaſily be detected.

To obtain tartareous acid, diſſolve 32 parts of D cream of tartar in water, and throw chalk into it gradually till it is completely ſaturated, a precipitate will be formed, which is tartrite of lime; decant the fluid, put the tartrite of lime into a matraſs, and pour over it nine parts of ſulphuric acid and five of water; digeſt the whole for ſix hours, taking care to ſtir it from time to time; the tartareous acid will then remain free, and may be ſeparated, by means of cold water, from the ſulphate of lime which has been formed, and may be cryſtallized by ſuffering it to evaporate ſlowly.

E To ascertain whether the tartareous acid contains sulphuric acid, let fall into it a few drops of acetate of lead: if the precipitate, which is formed, be entirely soluble in acetous acid, the fluid contains no sulphuric acid; if it is not soluble, sulphuric acid is present: to free it from this the fluid must again be digested over another quantity of the tartrite of lime.

F Malic acid. This acid is found in the juice of unripe apples, and in those of barberries, elder-berries, gooseberries, plums, and the common house-leek. It cannot be obtained in a crystalline form, but appears always in the liquid state. Its taste is unpleasantly sour. If left exposed to the air it gradually undergoes a spontaneous decomposition. Nitric acid converts it into oxalic acid.

G To prepare malic acid, take the juice of apples, saturate it with potash, and then add a solution of acetate of lead, till it no longer occasions a precipitate; wash this precipitate, which is malate of lead; pour over it sulphuric acid till the liquor acquires an acid taste without any mixture of sweetness, and then filter the whole, in order to separate the malic acid from the sulphate of lead which is formed.

Malic acid is also obtained by adding to the expressed juice of house-leek, a solution of acetate of lead, till no further precipitate ensues. The precipitate, after being washed, may be decomposed by sulphuric acid as before.

H Gallic acid exists in the gall-nut, in the husk of nuts, in oak bark, and in all those vegetables commonly called astringents.

Gallic

Gallic acid appears in the form of minute needle-ſhaped cryſtals. Its taſte is ſour, and auſtere or aſtringent. It ſtrongly reddens blue vegetable colours. It is ſoluble in about 10 parts of cold, and in three of boiling water. It is not altered by expoſure to air. Expoſed gradually to a gentle heat it ſublimes without alteration, but if expoſed to a ſtrong heat, quickly applied, it becomes decompoſed into carbonic acid, and carbonated hydrogen gas. It has a ſtrong tendency to unite with metallic oxids. With the red oxid of iron it produces a deep black precipitate. This combination is the baſis of ink and black dyes.

Gallic acid may be obtained, according to 1
Scheele, in the following manner: Reduce a pound of nut-galls into powder, and pour upon it ſix pounds of diſtilled water: Leave this mixture to macerate for the ſpace of 15 days at a temperature of from 68° to 77°. Then filter the liquor; and after the filtration, expoſe it in a veſſel of glaſs or ſtone-ware, to evaporate ſlowly in the air. During this evaporation, which may be continued during two or three months, the gallic acid will be depoſited in cryſtals, on the ſides and bottom of the veſſel, and on the inferior ſurface of a pellicle which will have formed over the mixture. At the end of this period, pour off the liquor. Then diſſolve whatever remains in the veſſel in alcohol. This laſt ſolution, evaporated, will afford the pure gallic acid in cryſtals.

Gallic acid may likewiſe be obtained by expoſing powdered nut-galls in a retort to a moderate heat. The acid by this means ſublimes; part condenſes in

ſmall

ſmall white cryſtals, and part is obtained in a fluid form, from its combination with a portion of water in the galls.

J Citric acid exiſts in the juice of lemons and oranges, and other ſour fruits.

It cryſtallizes in rhomboidal priſms, which ſuffer no alteration from expoſure to air. They are eaſily diſſolved by water, and excite a very ſour taſte, which, when diluted, is exceedingly pleaſant. One part of boiling water diſſolves two of citric acid. It acts upon iron, zinc, tin, lead, and various other metals. Nitric acid converts it into oxalic and acetic acid. Expoſed to a red heat, it becomes decompoſed into carbonic acid, and carbonated hydrogen gas, and a little charcoal remains behind. It may be obtained in the following manner:

K Saturate any quantity of boiling lemon juice, by adding to it gradually, pure chalk, in ſmall quantities, until the effervеſcence ceaſes, on adding to it a new portion of chalk. During this proceſs a white precipitate will be formed, and fall down to the bottom, conſiſting of citric acid and lime, (citrate of lime). Separate this precipitate by transferring the whole on a ſtrainer, and pour water over it till this fluid paſſes taſteleſs. Transfer the waſhed precipitate into a matraſs, or other convenient veſſel, and pour over it as much ſulphuric acid as will neutralize the chalk employed, having previouſly diluted the acid with ſix times its weight of water. Boil the whole about half an hour, agitating it with a wooden ſpatula during the whole time, and then pour it on a filter, taking care to

return

return the fluid, which paſſes through, back upon the filter until it becomes perfectly clear. Having done this, evaporate the fluid in a ſhallow veſſel to the conſiſtence of a thin ſyrup, and leave it to cryſtallize undiſturbed. The cryſtals obtained are citric acid; in order to obtain them in a ſtate of purity they muſt be rediſſolved, the ſolution muſt be filtered, and recryſtallized repeatedly. Four parts of chalk require in general, for ſaturation, 94 parts of lemon juice. The citrate of lime produced amounts to about 7½ parts. To decompoſe this, nearly 20 parts of ſulphuric acid are neceſſary.

Succinic acid exiſts in the ſubſtance called amber. L
It cryſtallizes in white tranſparent triangular priſms. It may be melted and ſublimed, but ſuffers a partial decompoſition. It is ſoluble in alcohol. It may be obtained by expoſing amber to heat. The acid ſublimes, and may be purified by repeated ſolution and cryſtallization.

Benzoic acid exiſts in the reſin called benzoin, and M
various other odoriferous ſubſtances. Benzoic acid cryſtallizes in priſmatic cryſtals. It has a pungent taſte. It fuſes by heat, is ſoluble in alcohol and ſulphuric acid.

Benzoic acid is beſt obtained by boiling repeatedly N
four parts of powdered benzoin with one of lime, in four parts of water, filtering the ſolution, and adding to it muriatic acid, till no further precipitate enſues. The precipitate obtained is benzoic acid. It may be purified by repeated ſolutions, filtrations, and cryſtallizations.

Benzoic

O Benzoic acid may alſo be obtained by expoſing benzoin in a crucible to a gentle heat, and covering the crucible with a cone of blotting paper. The acid ſublimes, and affixes itſelf to the paper.

P Camphoric acid cryſtallizes in white parallelopipeds. It has a bitter taſte, effloreſces in the air, is ſoluble in alcohol, and very volatile. For obtaining camphoric acid, camphor muſt be repeatedly diſtilled with nitric acid; cryſtals will then appear, which after being waſhed are camphoric acid.

Mucous acid is a white gritty powder, of a ſlight acid taſte, ſparingly ſoluble in water, but more ſo in
Q alcohol. To obtain mucous acid, take one part of gum-arabic reduced to powder, put it into a retort, and pour over it two parts of nitric acid; heat the mixture gradually, keep it boiling for about a quarter of an hour, and then ſuffer it to cool; a white powder will ſeparate, which after being waſhed is mucous acid.

Mucous acid may be obtained, by treating ſugar of milk with nitric acid, in a ſimilar manner.

R Pruſſic acid. This acid derives its name from the well known pigment called Pruſſian blue.

Pruſſic acid exiſts in the form of a colourleſs fluid. It has a ſtrong odour greatly reſembling that of peach-tree flowers, or of bruiſed bitter almonds. Its taſte is ſweetiſh but acrid. It is very volatile and inflammable when in the ſtate of vapour or gas. It does not redden the moſt delicate vegetable blues. It is eaſily decompoſable at high temperatures, and becomes converted into ammonia, carbonic acid, and carbonated hydrogen gas. It does not act upon any of the metals,

but

but readily unites with moſt of their oxids. It has a great tendency to form triple compounds with alcalies and metallic oxids, and in that ſtate it decompoſes all metallic ſalts, and hence it is one of the moſt important reagents of the chemiſt.

Pruſſic acid may be eaſieſt obtained by diſtilling two parts of Pruſſian blue with one of ſulphuric acid, previouſly diluted with ſix of water.

Lactic acid exiſts in the whey of milk.

Milk in a ſhort time grows ſour and thick during ſummer. By filtration and evaporation the curds may be ſeparated, and the whey is found to contain this acid. The whey being evaporated to one eighth, for the more effectual ſeparation of the curd, and then ſtrained, the acid is to be ſaturated with lime. Phoſphate of lime is by this means precipitated, becauſe deprived of the exceſs of acid that before rendered it ſoluble; but the acid of milk, forming a ſoluble compound with the lime, ſtill remains ſuſpended: the former is therefore ſeparable by filtration. A ſolution of acetate of lead being added, ſeizes the lime, and leaves the acid of milk again uncombined. Spirit of wine diſſolves this acid, but none of the other ſubſtances that remain in the whey. Evaporate the water, which would impede the action of the ſpirit by diluting it, and when the maſs is of the conſiſtence of honey, add the ſpirit. To this acid ſolution, after filtering, add pure water. Diſtillation will carry off the ſpirit, and leave in the retort pure acid of milk, diſſolved in water. The acid of milk yields no cryſtals,

cryſtals, and when evaporated to dryneſs, deliqueſces again. It is deſtructible by fire, affording water, a weak acid, aerial acid, inflammable air, and coal. It exceeds vinegar in attractive power.

Suberic acid, or acid of cork.

v Suberic acid may be produced in a ſolid form. It is volatilized by heat. It has a ſharp acid bitteriſh taſte; it acts ſtrongly upon the throat and excites coughing. It ſtrongly reddens vegetable blues, and has the peculiar property of turning the blue ſolution of indigo in ſulphuric acid to green. It is difficultly ſoluble in cold, but eaſily ſoluble in boiling water. When urged by the heat of a blow-pipe, it fuſes, becomes dry, and at laſt ſublimes entirely. It may be obtained in the following manner:

w Introduce one part of cork cut into ſmall pieces into a retort, and pour upon it ſix of nitric acid, diſtil the mixture with a gentle heat till no more nitrous gas appears. Then pour the contents into a baſon, and evaporate it till it acquires the conſiſtence of honey, and a pungent ſuffocating vapour ariſes; then add to it twice its bulk of boiling water, heat it gently and pour it on a filter. The fluid which paſſes, when cooling depoſits a precipitate, which muſt be ſeparated; the fluid is then evaporated to dryneſs, and the product obtained is ſuberic acid.

x Sebacic acid. This acid exiſts in a concrete form. It is void of odour. Its taſte is ſlightly acid. When heated it liquefies like tallow. It is ſoluble in cold water. Boiling water diſſolves it very readily. It is

also soluble in alcohol. It precipitates the acetites and nitrates of silver and mercury. It may be obtained in the following manner:

Distil hog's lard, wash the product with hot water, Y and drop into it a solution of acetite of lead, till it occasions no further precipitate. Collect this precipitate, wash it, and dry it. Having done this, pour over it sulphuric acid, and heat it; a substance resembling fat will then appear on the surface. This, being collected, dissolved in boiling water, and suffered to cool, crystallizes, and is sebacic acid.

## CHAP. XII.

### FERMENTATION IN GENERAL, AND ITS PRODUCTS.

IT is well known that all organised substances after Z life, suffer certain changes if placed in a due temperature, and in contact with air and water. Our present object, however, is to consider only such changes as must be examined by the chemical philosopher on account of the light they throw upon many of the phenomena of nature and art: It is therefore proper to give the theory of fermentation, of which five kinds are distinguished, namely, the saccharine, which produces sugar; the vinous, which produces wine, beer, &c.; the panary, which produces bread; the acetous, which produces vinegar; and the putrefactive which produces ammonia.

A Saccharine fermentation. The grain of barley, or other corn when moiſtened and expoſed to the air at about 50°, ſoon ſwells and ſhows marks of germination, by puſhing forth a radicle. If the fermentation be then checked by expoſing them to a conſiderable degree of heat, they will be found to be changed, in part, into a ſweet ſaccharine ſubſtance.

The oxigen of the air in contact with the ſeeds is at the ſame time converted into carbonic acid gas, by combining with part of the carbon of the ſeed; and there is a conſiderable evolution of heat in the fermenting maſs, to ſuch a degree as ſometimes to cauſe it to burn. Similar phenomena occur in the maturation of fruits, during the drying of hay when put up too wet, &c.

B Vinous fermentation. The conditions neceſſary for the vinous fermentation are the preſence of ſugar extract, mucilage and water, in a temperature of about 70°. When theſe circumſtances exiſt an inteſtine motion commences in the fluid, it becomes turbid, heated, and bubbles are diſengaged, conſiſting of carbonic acid gas. After a time the fermentation ceaſes, the dregs partly riſe to the top, and partly ſubſide to the bottom, the liquor becomes clear, having loſt its ſaccharine taſte, and aſſumed a vinous one. The ſubſtances moſt commonly ſubjected to this fermentation are the juice of the grape, the juice of apples, and other fruits, and an infuſion of malt, which when fermented with yeaſt forms beer. The briſkneſs and ſparkling appearance of ſome of theſe liquors depends on their being put into cloſe veſſels before the fermentation is completed;

pleted; by which means a quantity of carbonic acid gas is retained.

Acetous fermentation. If wine or any other vinous C fluid be expoſed to a heat, from 75° to 85° F. and air be admitted, the properties of the fluid are altered remarkably, it loſes its taſte and odour, it becomes ſour, and turns into vinegar, without the emiſſion of carbonic acid gas. During this change the fluid is firſt rendered turbid, its ſurface becomes covered with a mouldy pellicle, a quantity of fibrous matter ſeparates, and forms a kind of ſkin which ſinks down to the bottom, vulgarly called mother of vinegar. The liquor gradually becomes clear.

The moſt uſual method of making vinegar is by D means of two veſſels, each containing ſome refuſe of grapes, and ſuch matters; one of theſe is filled with wine, the other is half filled. In the latter the fermentation firſt begins, at which time it muſt be checked by filling this veſſel out of the other. Soon after the fermentation takes place in the other, at which time this is to be refilled in turn and ſo the proceſs goes on alternately for ſome weeks, when the vinegar is made.

Vinegar may alſo be prepared from water, containing E raiſins or ſugar, about three pounds to the gallon, or the fœces or dregs of apples, pears, &c. from which the juice has been expreſſed.

Vinegar fully fermented is clear and nearly colour- F leſs, it has a pleaſant pungent odour, and a ſour taſte. It poſſeſſes all the properties of an acid. When freed from its mucilage, and other heterogeneous admixture by diſtillation, it conſtitutes acetous acid.

G Panary fermentation is leſs underſtood than thoſe already noticed. A paſte of wheat-flour and water expoſed to a temperature of 65° ſwells, emits a ſmall quantity of gas, and acquires new properties. The gluten diſappears, and it acquires a ſour diſagreeable taſte. If a juſt proportion of this fermented paſte or leaven, or what is ſtill better, if ſome barm be formed into paſte with wheat-flour and water, the ſame fermentation is excited, without the diſagreable taſte being produced; the gas evolved is prevented from eſcaping by the viſcidity of the paſte which, therefore, ſwells; and if baked, forms light ſpongy bread.

H Putrefactive fermentation. When the ſpontaneous decompoſition of vegetable ſubſtances is ſuffered to proceed beyond the production of the acetous acid, the vinegar gradually becomes viſcid and foul, air is emitted with a fetid odour, an earthy ſediment is depoſited; and when the whole proceſs is finiſhed ſcarcely any thing remains but the ſalts, the charcoal and the earths which formed a conſtituent part of the vegetable. The fluid, if any is left, conſiſts of water and acetous acid. This decompoſition is called putrefactive fermentation, its

I properties being more ſtriking in animal matter. In animal matters the phenomena which attend are the following: The colour of the ſubſtance firſt becomes paler, its texture ſoft, it acquires an intolerably fetid odour, its organization is deſtroyed. The ſubſtance increaſes in bulk, air bubbles are diſengaged, and the whole becomes gradually converted into a greeniſh black matter of a pulpy conſiſtence, and laſtly fluid; a phoſphoreſcent light is frequently emitted. In this ſtate it

remains

remains for some time, sending forth a horrible offensive odour. This odour gradually disappears, the soft substance acquires more and more consistence, and becomes at last converted into a dry friable powder resembling a mixture of earth.

It is obvious, that during this process all the principles which form the organized animal matter, act upon each other according to certain laws, the precise nature of which has not been hitherto accurately ascertained. The gases which are developed, and which fill the cavities and cellular texture, so as to inflate and puff up the body are, evidently, ammonia formed by the union of the nitrogen and hidrogen of the animal matter, and afterwards phosphorated hidrogen, sulphurated hidrogen, carbonated hidrogen, and carbonic acid. In some cases nitric acid is formed. The earthlike residue which remains after the process of putrefaction has taken place, consists of charcoal with other earthy and saline matters. Thus it appears that the elements which formed the organized animal body, unite together during the process of putrefaction, two and two, and form a new set of binary compounds of a more simple nature, which enter again with other substances, under favourable circumstances, into new combinations, and thus serve for the reproduction and support of dead or living matter.

# BOOK III.

## SECTION II.

## Of Magnetifm.

### CHAP. I.

CONCERNING MAGNETISM; THE METHODS OF COMMUNICATING IT, AND THE VARIATION OF THE COMPASS.

A THAT remarkable property which iron poffeffes, of becoming magnetical, feems to ftand alone among natural phenomena. It is the only inftance of permanent attraction which is fufficiently ftrong to become the object of vulgar attention; and philofophers obferve its effects with furprife and admiration, while the moft cautious and rational are obliged to confefs that the caufe is entirely unknown.

B A ftraight bar of iron, which in the northern parts of the world has ftood a long time in a vertical pofition, is found to have acquired the property of attracting other iron at its extremities; and, if fupported in a veffel, fo as to float at liberty upon water, conforms itfelf to a direction nearly in the plane of the meridian; the end, which

which during its perpendicular situation was downwards, always pointing towards the North. This bar is said to be magnetical; and the unknown cause of these and other concomitant effects is called magnetism.

Magnetism may be given to iron, or rather steel, by many methods. The disposition to conform to the plane of the meridian is called polarity, and is of such importance in its application, that the modern art of navigation could not be practised without it. The mariner's compass is thus constructed. A flat thin bar of steel, rendered magnetical, is fastened underneath a circular card, divided into points (56, K), so that the direction of its length may correspond with the line N S (fig. 132, Pl. XXII). This bar is perforated in the middle; and in the perforation is fixed a brass cap, hollowed out conically, which consequently is in the centre of the card. The card thus provided with a magnetical bar, is then supported horizontally, by placing the cavity of the cap on an upright metallic point, and is therefore at liberty to revolve into any horizontal position. But the bar, which is usually termed the needle, conforming itself to the meridian, causes the fleur de lis of the card to point to the North: consequently, the other divisions must denote the respective bearings of the points of the compass. This card being thus suspended in a hollow box, and defended from the wind by a pane of glass, with the addition of a contrivance to prevent the effects of the agitation of

the ſhip, is the mariner's compaſs; by the help of which, veſſels are enabled to ſteer their courſe with ſafety in the darkeſt night, and at any diſtance from ſhore.

D In the examination of the magnetiſm of various bodies, as for example, platina (167, B) or nickel, it may be of importance to know the degrees of magnetiſm as diſcoverable by experiment, which are the following. The weakeſt is when a body floating on water ſlowly follows a ſtrong magnet, held almoſt touching it: the next is when the magnet can repel as well as attract the body; a ſtill ſtronger degree is, when the body conforms its poſition to that of the magnet held over it; the fourth is when the body left to itſelf aſſumes a particular poſition, and returns to it when diſturbed; the fifth is, when the body, taken out of the water, and brought near a light compaſs needle, cauſes it to deviate from the magnetic meridian. All ſtronger degrees of magnetiſm may be obſerved by leſs delicate methods.

E The ends of a ſimple magnetical bar are called its poles; and that pole, which, when at liberty, would point to the North is called the North-pole, and the other is called the South-pole.

F Univerſally, in two magnetical bodies or magnets, an attractive force obtains between the North-pole of one, and the South-pole of the other, and a repulſive force obtains between poles of the ſame name. But the repulſive force which exiſts between

tween poles of like names, but unequal power, is changed into attraction, when the diſtance is ſufficiently ſmall. From theſe criterions it is eaſy to determine the names of the poles of a magnetical bar by applying it near a ſuſpended magnet, the poles of which are known.

If a bar of iron, which is not magnetical, be held in a vertical poſition, in North latitude; its lower point becomes a North and its upper a South pole; and theſe poles may be reverſed inſtantly, and as often as required, by reverſing the poſition of the ends; for the lower will always be North, and the upper South. But a few ſtrokes with a hammer at the upper end, will fix the poles in their laſt poſition, ſo that, after the reverſing it the hammered end will ſtill continue to be ſouth, though loweſt. Yet, the magnetical power is much the greateſt when the hammered end is uppermoſt, and the effect of the hammering diſappears in a few hours.

A bar of iron being ſuſpended on an axis, in a very nice equilibrium, the North end preponderates when the bar is rendered magnetical, ſo that it becomes inclined to the horizon, in an angle of about ſeventy degrees in theſe latitudes. This is called the dip, and decreaſes in places more to the ſouthward, and even becomes inverted in places ſituated conſiderably on the other ſide of the equator. The bar thus ſuſpended is termed the dipping-needle.

I Magnetiſm may be given to a bar of iron, by placing it firm in the poſition of the dipping-needle, and rubbing it hard all one way with a poliſhed ſteel inſtrument. Iron alſo becomes magnetical by ignition, and quenching it in water, in the poſition of the dipping-needle.

K The touch of a magnet communicates the like virtue to other iron, but the quantity or degree which the ſame magnet can communicate, depends greatly upon the manner in which the touch is performed. If two equal, ſtraight and uniform magnetical bars, with flat ends, be placed together endwiſe, the contrary poles touching each other, they will form one ſingle magnet, and will communicate a ſtrong degree of magnetiſm to another bar by the following proceſs: let the laſt mentioned bar be laid in the direction of the magnetical meridian, and let the others, each of which ought to be at leaſt as long as the bar to be impregnated, be laid upon it in their conjoined ſtate, ſo that the place of junction may be over the middle of its length, and their poles in the proper direction. Then ſeparate the two magnets, by drawing them aſunder along the ſurface of the bar, and continue to ſeparate them till their ends are at a conſiderable diſtance from its ends. Join them again, without altering the ſituation of their poles, by a circular motion of the hand, ſo that they may meet at ſome diſtance above the centre of the bar, and lay them again upon it as before. Repeat this operation on both ſides

ſides of the bar till it has acquired a ſufficient degree of magnetiſm. The maximum is generally obtained after twelve or fourteen ſtrokes.

A bar of iron receives the touch more ſtrongly L when it is ſupported by, or in contact with, another much larger; and a combination of magnetical bars will produce a much greater effect than a ſingle one. Soft ſteel acquires the magnetical power more readily, but does not preſerve it ſo long as hard ſteel. On theſe, and other conſiderations, experiments have been multiplied, and various methods invented of giving to ſteel the utmoſt degree of magnetiſm it is capable of receiving. For example, ſix bars of ſteel may be M rendered ſlightly magnetical, by affixing each ſucceſſively to a poker, and ſtroking it ſeveral times from bottom to top with the lower end of an old pair of tongs; care being taken to keep both the poker and tongs in a vertical poſition. For, theſe utenſils, by long ſtanding in a vertical poſition, are almoſt always poſſeſſed of a fixed magnetiſm; the lower ends being North poles. Now, if four of the ſix bars be united into a thick compound bar; the magnetiſm of the remaining two may be greatly increaſed by touching with it. Theſe two bars may then be ſubſtituted in the room of the two outermoſt in the compound bar, which will become more powerful by the exchange, and the two, which were taken from the compound bar, may be touched in their turn. Thus, by reiterated changes,

changes, and touching, the bars will at length acquire as much magnetiſm as they are ſuſceptible of, and more than they can retain for any long time.

N The force of magnetiſm is exerted through all ſubſtances, iron excepted, and it has not been obſerved, that it ſuffers the leaſt diminution by the interpoſition of any foreign matter. Magnetiſm is deſtroyed by ignition; and a heated bar of iron is not attracted by the magnet till it is juſt upon the point of loſing its redneſs.

O The loadſtone is a ponderous ore of iron, uſually of a dirty black color, and hard enough to emit ſparks with ſteel. It is found in moſt parts of the world, and poſſeſſes a natural magnetiſm, acquired moſt probably from its ſituation or poſition with reſpect to the earth. This magnetiſm may be, as it were, concentrated, and made to act much more ſtrongly by covering its polar extremities with ſteel. The ſteel thus applied is termed the armour of the loadſtone, and requires ſome management, as to figure and thickneſs, to produce the greateſt poſſible effect. Formerly all magnetiſm was originally obtained by communication from the loadſtone, but the power of impregnated ſteel-bars ſo much exceeds that of the natural ſtone, that this latter is little eſteemed, except as an object of curioſity. The magnetiſm of the loadſtone is in all reſpects ſimilar to that of a bar of iron or ſteel.

P The attraction or repulſion of two magnets decreaſes as the diſtance increaſes, but not according

to any ratio of the diſtance. On this account a magnetical bar, which is at liberty to aſſume any horizontal poſition, as, for example, a needle floated on water by means of cork, or the needle of a mariner's compaſs, being brought into the vicinity of another magnet, will aſſume ſuch a ſituation as ſhall conform to the attractive and repulſive powers as much as poſſible. Thus, if a ſuſpended magnetical needle be brought near another magnet, it will place itſelf in a poſition parallel to the axis of the magnet, if the poles of contrary names in each be mutually equidiſtant; but if the North pole of the ſuſpended needle be nearer the South pole of the magnet than the two other poles are to each other, its North end will be moſt attracted, and conſequently muſt incline, ſo that the axis of the two magnets will form an angle greater or leſs, according to circumſtances. Suppoſe now a ſmall magnetical bar, ſuſpended ſo as to be capable of aſſuming any poſition whatſoever, be placed upon or near the ſurface of a very large globular magnet. It is evident, in this caſe, that the two ends of the ſmall bar, being reſpectively attracted by the contrary poles of the globe, will always be found in a plane paſſing through thoſe poles: or in other words, if circles or meridians be ſuppoſed to be deſcribed on the globe, interſecting each other in thoſe poles, the magnetical bar muſt always be in the plane of one of them. But its ſituation, with regard to the ſpherical ſurface, will be governed by the exceſs of

attraction

attraction in the neareſt pole. If the bar be ſuſpended immediately over the North pole of the magnet, it muſt ſtand perpendicularly, with its South end downwards; but if it be gradually removed along the ſurface, towards the South pole, the increaſing action of this laſt pole will cauſe it gradually to incline that way. At the equator it will reſt parallel to the ſurface; and in approaching ſtill nearer the laſt mentioned pole, its North end will incline towards the ſurface, till at length it will ſtand perpendicularly over the South pole of the great magnet, with its North end downwards. For the ſake of conciſeneſs, the poles of the great magnet are ſuppoſed to be equally ſtrong; which, however, is ſeldom the caſe.

R This reaſoning may be exemplified by placing a ſmall piece of a ſewing-needle on the ſurface of a ſpherical magnet or loadſtone. Its poſition is found to vary according to its ſituation with reſpect to the poles. For the ſame reaſons, ſteel-filings, gently duſted through a rag upon a magnet, adhere to it in a very curious and amuſing manner. The filings, acquiring magnetiſm by the contact, adhere together, and form a number of ſmall magnets, which arrange themſelves in conformity to the attractions of the poles of the original magnet.

S From obſervations of this nature, it was very early ſuppoſed, that the globe of the Earth acts as a large magnet, upon all other magnets: whence they naturally tend to conform to the meridian or

line

line which joins the poles of the Earth. And the r dipping of the needle is readily ſhewn to ariſe from the vicinity, and conſequent ſtronger attraction of the pole towards which the inclination is made.

The needle of the mariner's compaſs varies from u the true direction of North and South. The angle formed between the magnetical axis of the needle and the meridian of a given place is called the variation of the compaſs, and differs in different places both in quantity and direction of the needle. From the phenomena of the variation it is proved, that the magnetic poles of the Earth muſt be more in number than two, and that they do not coincide with the poles about which the diurnal rotation is performed.

The variation of the compaſs does not continue v fixed and unalterable at a given place. Thus, at the Cape of Good Hope in Africa, near which, at its firſt diſcovery by the Portugueſe, there was no variation; the North point of the compaſs, in 1622, varied about 2° to the weſtward: in 1675, it varied 8° W. in 1700, about 11° W. in 1756, about 18° W. and in 1774, about $21\frac{1}{2}$° W. Regular, though very different mutations have been obſerved in almoſt every other place on the globe. The needle of the compaſs is likewiſe ſubject to a ſmall diurnal change of poſition, and is ſometimes conſiderably agitated during the appearance of the aurora borealis.

The obſervations which relate to the magnetiſm w of the Earth have not been continued long enough

to

to afford a foundation for a good theory. Dr. Halley's hypothesis, though formed near a century ago, still possesses as great a share of probability as most that have been offered since. He supposes the Earth to consist of two distinct parts, an external shell, or hollow sphere, and an internal nucleus or globe, loose and detached in the cavity, having the same centre of gravity with the external part. Each of these parts he regards as a separate magnet, endued with two poles, their magnetical axes not being coincident. A compass-needle on the external surface must therefore be acted upon, as if by a magnet with four poles. From the phenomena he determines the situation of the several poles; and thus explains the variation. But as the variation changes in process of time at any given place, it follows, that these poles do not keep the same position with respect to the surface of the Earth, and to each other. This movement he accounts for, by supposing that the diurnal motion of the Earth was impressed from without, and that the velocity of the internal part, or nucleus, is somewhat less than that of the external part, or shell. Consequently the nucleus must seem to revolve slowly to the westward, and its poles must describe less circles about the poles of the Earth. And as the relative position of the four magnetical poles to each other, and to the poles of the Earth, is changed, so must likewise the direction of the needle,

needle, or the angle it makes with the meridian, be altered.

Thus, a kind of regularity prevails in the increase and decrease of the variation, and also the direction of the variation which ships observe as they sail to various parts of the ocean. In the Atlantic ocean to the North, and eastward, and all over the Indian ocean, except in the bay of Bengal, a westerly variation obtains; but to the westward of a certain line, at which there is no variation, all along the coast of South America, and in the Pacific ocean, as far as the 140th degree of west longitude, an easterly variation is observed; and in the whole Pacific ocean besides, the variation is probably to the west, unless it may be conjectured that an easterly variation may be found in the regions to the northward. Y

When the variation changes quickly in running upon a parallel, as is the case in the southern Atlantic, and great part of the Indian ocean, the longitude may be determined with a considerable degree of correctness at sea. For the magnetic azimuth of the Sun may be easily observed in moderate weather to the certainty of a less error than ten minutes of a degree; which in the southern Atlantic ocean answers to about twice that quantity in longitude. By comparing the observed variation with a chart, the longitude may be known. The principal impediment in the way of this method is, the want of such a chart occasionally renewed. Z

A The beſt modern opinion concerning the cauſe of the change of variation of the compaſs is this: From the magnetiſm of the Earth as well as from the products ejected by volcanoes, it is eſtabliſhed that vaſt quantities of iron exiſt in the bowels of the Earth in various ſtates. The ſame volcanic eruptions, and the phenomena accompanying them, likewiſe ſhew that chemical proceſſes, on a ſcale of prodigious magnitude, are continually carried on in thoſe regions. The ferruginous combinations being varied by theſe, it muſt happen that immenſe maſſes will be either more or leſs oxigenated according to the nature of the proceſs by which ſuch change is made. Now it is well known that iron and its combinations are more ſuſceptible of magnetiſm the nearer the metal approaches to the pure metallic ſtate: and conſequently the properties of the whole terreſtrial magnet muſt change accordingly.

# BOOK III.

## SECT. IV.

## Concerning Electricity.

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### CHAP. I.

#### OF THE ELECTRIC MATTER; AND THE METHODS AND APPARATUS FOR MAKING EXPERIMENTS WITH IT.

If a tube of glaſs, an inch and half in diameter and about three feet long, be rubbed, by repeatedly drawing the hand, a piece of leather, or a will of dry warm ſilk, from one end to the other, it piece become electric. So that ſmall flaſhes of divergent flame, ramified ſomewhat like trees bare of leaves, will dart into the air, from many parts of the ſurface of the tube, to the diſtance of ſix or eight inches, attended with a crackling noiſe; and ſometimes ſparks of more than a foot in length will fly along the tube to the rubber. This luminous matter is called electricity, or the electric matter, and will fly from the tube to other bodies brought within a certain diſtance.

B If a homogeneous body be preſented to the ex-
cited tube, ſo as to receive electricity from it, and
the electricity remain at or near the end or part pre-
ſented, without being communicated to the reſt of
the body, it is called a non-conductor or elec-
C tric. But if, on the contrary, the electricity be thus
communicated to every part, the body is called a
D conductor, or non-electric. In the uſual tempe-
rature of the atmoſphere, metallic ſubſtances, char-
coal, and water are conductors; moſt other bodies
are non-conductors.

E A conductor cannot be electrified while it com-
municates with the earth, either by direct contact
or by the interpoſition of other conductors, becauſe
the electricity is immediately conveyed away to
F the earth. But if a conductor be ſupported by an
electric, ſo as not to communicate with the earth,
it is ſaid to be inſulated, and may then be electrified,
the electricity not being conveyed away.

G The greateſt quantity of electricity is collected
on the ſurface of a non-conductor, when it is rub-
bed by a conducting ſubſtance. If the rubber be
inſulated, it will alſo be put into an electric ſtate,
ſo that ſparks will paſs between it, and other neigh-
bouring bodies.

H If an inſulated conductor be electrified, either by
friction, communication, (274, B) or otherwiſe, it
will be deprived of its electric ſtate by the drawing
of a ſingle ſpark from any part thereof by another
uninſulated conductor, becauſe of the facility with
which the electric matter is conveyed through its
ſubſtance. But non-conductors, ſimilarly treated,

are

are deprived of their electric state only in the vicinity of the place from which the spark was drawn.

A mutual attraction is exerted between a body I
in a state of electricity, and non-electrified bodies; which last, if not large and heavy, will fly through the air to the electrified body, where they remain till they have, by communication, acquired the same state, when they are repelled. If an uninsulated conductor be at hand, it will attract the small body thus electrified, and deprive it of its electric state. So that it will be again attracted by the electrified body, and repelled as before, and will continue to pass and repass between the two for many vicissitudes, till the electric state is entirely destroyed.

No experiments have yet been made, that shew K
wherein the difference between electrics and non-electrics consists; but whatever the conducting power may depend on, it seems to be governed by the heat of the body: glass, resin, baked wood, air, and many other non-conductors, are conductors when made very hot; and on the contrary, ice cooled to 13° below 0, on Fahrenheit's scale, becomes a non-conductor or electric body.

There is therefore some ground to conjecture L
that the disposition to conduct electricity is produced in metals by a very low degree of heat, in water by a greater, and in resins and glass by degrees still greater; or generally that there is a certain degree of heat at which a given body may be

at the medium between perfect conducting, and non-conducting, above which degree it becomes a M conductor, and beneath a non-conductor. If this be true, it will follow, that conductors are bodies, the electric or non-conducting ſtate of which is placed at a temperature far below that which is uſual in the atmoſphere; and that non-conductors are thoſe the conducting ſtate of which is placed at a degree of heat far above the mean temperature.

N That electricity is real matter, and not a mere property, ſeems to be evident from a variety of circumſtances. When it paſſes between bodies, it divides the air, and puts it into thoſe undulations (65, N) in which ſound conſiſts. It emits the rays of light in every direction, and thoſe rays are variouſly refrangible, and colorific, as other light is. And if light be acknowledged to be matter, it is contrary to reaſon and experience to ſuppoſe, that the thing which emits it ſhould not likewiſe be material. Neither are the other ſenſes unaffected at its preſence; its ſmell is ſtrongly phoſphoreal or ſulphureous, ſo that when the air of a room is rendered highly electric, many perſons have complained of an unuſual and diſagreeable ſenſation in the head from that cauſe. The ſenſe of feeling is a witneſs of its preſence, not only from the ſparks, which, when received from the conductor of a powerful machine, are very pungent, and will paſs through two or three perſons ſtanding on the ground, but alſo from the ſhock, the effects of which are to be deſcribed: and a ſtream of the electric

matter

matter received on the tongue has an evidently ſubacid taſte, which remains ſome little time.

As the exciting a tube is very laborious for the operator, and the electricity procured by that means is ſmall in quantity, globes or cylinders are much more uſed. Theſe, by a proper apparatus, are made to revolve on their axes after the manner of a grindſtone, and a rubber of leather is applied to the equatorial parts of the revolving glaſs, which become electrical by the friction. The electricity of the globe is received by a metallic conductor, inſulated by a glaſs-foot, or ſupporter. This conductor being conſtantly electrified, and at the ſame time ſteady and motionleſs, is much better adapted for making experiments than the globe itſelf. O

A cylinder or globe thus fitted up to revolve on its axis, and provided with a rubber and an inſulated conductor, is called an electrical machine. The contrivances for the revolution of the cylinder or globe vary in different machines, as likewiſe the method of inſulating the conductor. The conductor is in general ſupported by a ſtick of varniſhed glaſs or baked wood, and ſometimes it is ſuſpended by ſilk ſtrings. P

Fig. 172. repreſents the plate electrical machine, which is now generally adopted in preference to the cylindrical. Q

The glaſs plate G G, fig. 172. Pl. 26. is faſtened to the axis B B, by means of a ſcrew on the axis paſſing through a hole in the centre of the plate, and ſecured by a nut

C on the oppoſite ſide. The axis is ſupported by a ſingle pillar A, which for this purpoſe is provided with a bearing piece K, on which are two braſs collar pieces, that carry the axis; and on the end of the axis, oppoſite the glaſs is a counterpoiſe O, of lead, to prevent too great a friction in the collar neareſt the handle. The arc of the conductor E E, which carries the two ſmall receiving conductors F F, is fixed to an axis turning in the ball H. On the other ſide of the plate is the other arc I, of braſs wire, fixed in the bearing piece K, but ſo as to admit of being turned round like the arc E E. P is a copper tube, moving like a radius on the ſtem of the ball S, which, being ſcrewed into the conductor H, ſerves to confine the arm P in any poſition that may be required. The diſſipation of electricity along the glaſs ſupports is prevented by a kind of cap T, of mahogany, which affords an electrical well or cavity underneath, and likewiſe effectually covers the metallic cap into which the glaſs is cemented. The lower extremity of the pillar is guarded in the ſame manner by a hollow piece or ring of mahogany V. The three glaſs pillars are ſet in ſliding pieces W W W, adjuſtable by ſcrews; at each extremity of the horizontal diameter of the plate are two rubbers X, one on each ſide, preſſed regularly and uniformly againſt the plate by means of a ſpring Y, the force of preſſure of which is regulated by means of a ſcrew. To theſe rubbers are attached ſilk flaps Z Z, thoſe of one pair of rubbers deſcending, and thoſe of the other pair aſcending, in the direction in which the plate is

worked.

worked. A piece of fine dry writing paper, as long as the rubber, and half an inch broader so as to cover the seam that fastens the silk to the leather, allows greater pressure to be employed by diminishing the friction, and prevents both the glass and silk from being soiled by the amalgam, so that the excitement is more powerful, and the amalgam requires to be renewed less frequently. As the semicircular branch of the prime conductor is moveable, it may be made to exhibit the electricity of the rubber at any time, by placing the cylindrical ends in contact with the cushions, the semicircular wire I, being at the same time turned so as to cross it at right angles, which insulates the cushions. When the conductor is required to give electricity from the glass, the arc I must be in contact with the cushions, and the arc E E perpendicular to the horizon.

Fig. 173. is a drawing of Nairne's patent electrical machine. The cylinder C is seven inches in diameter and about one foot in length, but the length of the rubber is no more than eight inches. The working parts at the end of the cylinder are entirely of wood, and are supported by two pillars of varnished glass, each of a foot in length. The conductors A and B, are supported by like pillars of the same dimensions. The two conductors are made of tin, and lie parallel to the length of the cylinder. They are exactly alike, excepting that the rubber is fixed between the conductor A and the cylinder, and a row of metallic points issue towards the cylinder from the other conductor B. R

The insulation of this excellent small machine is so perfect, that on the addition of a larger conductor to either of the others, it will give dense sparks of nine inches long to a ball of 2½ inches diameter.

CHAP.

## CHAP. II.

### CONCERNING EXCITATION; THE TWO DIFFERENT STATES OF ELECTRICITY; AND THE EFFECTS OF POINTED CONDUCTORS.

VERY little electricity is excited by the friction between two electrics or two conductors. The most favourable circumstances for producing this effect seem to be, when a perfect electric is rubbed by a perfect conductor (273, A).

The rubber of an electrical machine is usually made of soft leather stuffed with hair, and the rubbing part is smeared with an amalgam of zink and quicksilver with a little tallow, the whole being so proportioned as to have the consistence of paste. The glass cylinder, or plate, in its rotation, passing in contact with this metallic soft substance, becomes electrified, and its electricity is prevented from flying back in sparks to the rubber or being dissipated into the air, by a piece of silk sewed to the rubber, and passing thence half way round the cylinder, or over a fourth of the plate, to which it adheres by the electric attraction.

The electricity thus excited, is much stronger in dry frosty weather than when the atmosphere is damp, and consequently a better conductor of electricity. The management of the operator will also make a pro-

a prodigious difference. No theory of what happens in the excitation of electrics, has been offered that deserves to be mentioned; and it is owing to our imperfect knowledge of this subject, that the most skilful operators succeed by an attention to circumstances relating to the consistence of the amalgam, the roughness or smoothness of its surface, its freshness, the position and management of the silk, and other matters that can hardly be described, so as to assist the young electrician. The following directions however succeed very well.

v Every part of the apparatus must be carefully wiped with a dry warm cloth, or old silk handkerchief, in order that the electricity when collected, may not be conducted off by adhering moisture or damp (274, D). The amalgam ought to abound with quicksilver, and to have no more tallow than is sufficient, when applied to the cylinder, just to diminish its brightness without smearing. It must be rubbed on the rough side of a piece of leather, pasted on a card, in very small quantity. The cushion and silk must be carefully brushed or wiped before it is put into its place. This done, turn back the silk so that its loose part may not touch the cylinder, and begin to turn the machine, at the same time applying the amalgamed leather to the cylinder. After a few turns the electricity will be heard in a kind of rustling noise near the hand and cushion. Remove then the amalgamed leather, and replace the silk on the cylinder, to which it will immediately adhere.

adhere. The friction will now be much greater than before, as will be perceived by the difficulty of turning the handle, and the electricity will be ſeen along the edge of the ſilk in long diverging ramifications that dart into the air with noiſe. Theſe fly to the points of the prime conductor when applied, and, by means of this laſt, the ſparks may be drawn, or other experiments performed.

It is not well ſettled whether a velocity of rotation in the cylinder, greater than the hand can produce with a ſingle winch, be of any advantage in electricity. From a few trials, not ſufficiently diverſified, the fact ſeems to be, that there is a certain velocity of turning by which more electricity is obtained, in a given number of turns, than by any velocity conſiderably greater or leſs; and that this neceſſary velocity is leaſt when the excitation is moſt powerful. A cylinder of ſeven inches diameter, well excited, will afford its maximum of electricity in a turn by a moderate rotation with a ſingle winch, and the adheſion of the ſilk will render the turning ſufficiently laborious. But whether the labour of the operator would be better employed in producing more turns in a given time by means of a wheel, though the excitation were leſs powerful, remains to be decided.

If the amalgam be applied on the cuſhion itſelf, inſtead of a ſeparate leather, the excitation will be more uniformly the ſame, though rather leſs ſtrong. When the ſeparate leather is uſed, it is neceſſary

to apply it to the cylinder from time to time, to keep up the excitation. One of the chief advantages of this last method appears to be, that a strong excitation may at any time be produced by taking off the cushion and wiping it and the silk very clean, at the same time that the old amalgam is scraped off the leather and replaced by the size of a pea of fresh amalgam; whereas in the other method, it not unfrequently happens, that the operator is obliged to have recourse to a variety of manœuvres without success.

Y If of two conductors, separately insulated, one be connected with the insulated rubber, and the other placed near the cylinder, so as to be electrified by it, they will both exhibit signs of electricity; but that conductor, which is electrified by the cylinder, will attract those bodies which are repelled by the other conductor that received its electricity from the rubber. And these conductors, if brought near each other, will emit sparks, and act on each other in every respect stronger than on other bodies. If they be brought into contact, the electricity of the one will destroy that of the other; and notwithstanding the electric matter appears to flow or pass from the cylinder to its conductor, the two thus conjoined will exhibit few or no signs of electricity.

Z The senses cannot distinguish the direction in which the electric matter moves. The hypothesis most generally admitted is, that electricity is an uniform fluid, capable of being rarefied or condensed, and

and that in the common electrical machine it passes from the cylinder to the conductor with points. On this supposition this conductor must, when electrified, possess a greater quantity than is natural to it; and since the cylinder affords very little electricity when the rubber is insulated, it will follow that it receives its electricity from the rubber; for unless the rubber be at liberty to receive an equal quantity from the earth, that is, unless it be uninsulated, it can part with but a very small quantity to the cylinder. Still retaining the same supposition respecting the course of the electric matter, it follows that the rubber, when insulated, must lose a part of its natural quantity by friction with the cylinder, and consequently a conductor communicating with it must be negatively electrified. It is not therefore so much to be wondered at, that the actions of the two conductors should be contrary, and that when in contact they should exhibit no signs of electricity; for the cylinder at the same instant that it imparts the electric matter to one conductor, exhausts an equal quantity from the other, which is connected with the rubber. If the direction of the electric matter be supposed to be contrary to what is here assumed, the effects must still be the same.

The principal circumstance whereon the prevailing opinion concerning this direction is founded is, that if the conductor, which derives its electricity from the cylinder, be made sharp or angular at any part, not very near the cylinder, a diverging cone of electric light will be seen, the vertex of which is the point itself, and the electric phænomena will be much diminished.

minished. But the conductor, which is connected with the rubber, though its effects be equally diminished by a similar circumstance, will never exhibit the cone of rays, but is only tipped at the point with a small globular body of light. The cone has been thought to resemble the rushing out or emitting of light, and the globe the appearance of the imbibing or entrance of the electric matter; whence the name of positive electricity has been adopted for that of the cylinder, and negative for that of the rubber. The terms will be used in the same sense, in this work, though it must be confessed, that the propriety of their application is still doubtful.

B If electricity be produced by the excitation of a globe or cylinder of sulphur or resin, the states will be reversed; the rubber will be positive, and the cylinder, with its conductor, will be negative. This was formerly thought to depend on the nature of the electric body, and the two states of electricity were distinguished by the names of vitreous and resinous electricity, but it has since been found, that the difference, in most cases, arises from the relative smoothness of the surfaces of the electric body and its rubber when compared with each other.

C It seems to be a rule, that the smoothest of the two bodies obtains the positive state. Baked wooden cylinders, with a smooth rubber of oiled silk, become negative, but with a rubber of flannel positive. Glass, made rough by grinding with emery, excited with new soft flannel, is negative, but with dry oiled

silk,

ſilk, rubbed with whiting, poſitive; but if the glaſs be ſmeared with tallow, and wiped with a cloth, then the oiled ſilk, by rubbing, becomes poliſhed, and the tube becomes negative, as at firſt; if the oiled ſilk be again rubbed with whiting, it excites a poſitive ſtate on the greaſed tube; but when the ſilk has again acquired a poliſh, the tube becomes again negative. Even poliſhed glaſs may be rendered negative by rubbing with the hairy ſide of a cat's ſkin.

Bodies poſſeſſed of ſimilar and equal ſtates of elec- D
tricity, repel each other; bodies poſſeſſed of oppoſite ſtates of electricity, attract each other; and bodies in a mean or natural ſtate are attracted by all electrified bodies whatever. But as we have no clear conception, or adequate idea, of any mechanical proceſs by which attraction may be cauſed, all our reaſoning on the ſubject muſt be purely hypothetical (1. 25, x), for want of probable grounds to proceed on. If ever this property of matter, the origin of which at preſent is ſo little underſtood, ſhould be deduced from ſome ſimpler cauſe, there is great reaſon to think, that it will be in conſequence of electrical diſcoveries.

If the inſulated prime conductor of a machine be E
well poliſhed, and without corners or angles, it will retain its electric ſtate very well, and will emit ſtrong ſparks upon the approach of any uninſulated conductor. If the uninſulated conductor be broad, round, and poliſhed at the end, the ſparks will be ſhort and denſe, and will produce a conſiderable

ſound;

found; if lefs broad, the fpark will be long, crooked, and lefs founding; if the breadth be ftill more diminifhed, the conductor begins to come under the denomination of a pointed body (285, A), the electric matter paffes to it from the prime conductor, through a great fpace of air, with a hiffing or ruftling noife, and in a continual ftream: a ftill greater fharpnefs enables the electricity to pafs over a greater fpace, but filently, and nothing is feen but a fmall light upon the point. If a fimilar point iffue from the prime conductor, and the uninfulated conductor be round and polifhed, the fame effects happen in like fituations; but if both be pointed, the electricity is more readily difcharged: and in all thefe cafes the appearance of the electric matter at the point of the prime conductor will be that which is peculiar to its electricity, a large divergent cone if pofitive, or a fmall globular light or cone if negative, and the light at the point prefented to the prime conductor will be diftinctive of the contrary electricity. Whether a pointed conductor be electrified pofitively or negatively, if the nofe be brought near the point during the electrization, a wind will be felt blowing from the point, and the fenfe will be affected with a fulphureous or phofphoreal fmell.

F The reaction of the force by which the air is put into motion, is exerted on the pointed body. This is fhewn by a pleafing experiment with an electrified wire, thus; to the middle of the wire, or rather between two wires that lie in the fame line, is affixed

fixed a center-cap like those used in sea-compasses, so that the wire may easily be moved on a point in a horizontal direction, as magnetical needles are; and the ends of the wire are pointed and bent contrary ways, to point in the direction of the tangent to the circle described by them. Now if this wire, thus suspended on a point, be insulated and electrified, its sharp ends will become luminous, and it will revolve in a direction contrary to that in which its ends are bent; or if it be suspended on an uninsulated point, and brought near the electrified prime conductor, the same effect will follow.

It may be thought strange that the air should issue from an electrified point, whether its electricity be positive or negative. It is easy to conceive that the issuing out of the electric matter may cause the air to move in the same direction; but it appears strange, that the electric matter rushing towards a point should cause the air to move directly contrary, that is to say, likewise from the point. But if the circumstance be examined more narrowly, the difficulty will vanish. For it is highly probable that the electric matter passes too swiftly (1. 40, A) to excite any motion in the air but that undulation wherein sound consists (65, N); to which may be added that, if the electric matter do act on the air to put it in motion, the air must react with an equal force; and therefore that a current of air blown against the course of the electric matter must affect its appearance, by retarding the rays and deflecting those against which it struck obliquely: the contrary to which is, by experience, known to obtain; for

 the

the luminous cones (188, E) are not ſenſibly affected by ſuch treatment. The air being thus indifferent as to the motion of the electric matter, its motion may be ſhewn to depend on the eſtabliſhed principles of electricity. The point is electrified either poſitively or negatively, and the air, immediately oppoſite and contiguous to the point, muſt, by the emiſſion or exhauſtion of the electric matter, become ſtrongly poſſeſſed of an electric ſtate of the ſame kind with that of the point: it is therefore repelled (187, D) and replaced by other air which is alſo electrified and repelled, by which means a conſtant ſtream is produced blowing from the point, and that equally whether the electrization be poſitive or negative. And, as action and reaction are equal and contrary, the point repelling the air muſt itſelf alſo be equally repelled in the contrary direction; whence the horizontal wire above deſcribed is turned, and that always one way, namely, contrary to that in which the air is moved, or to the direction of its bent points.

## CHAP. III.

### OF THE COURSE OF THE ELECTRIC MATTER THROUGH THE COMMON AIR, AND THROUGH AIR VERY MUCH RAREFIED, WITH A DESCRIPTION OF AN INSTRUMENT FOR DISTINGUISHING THE TWO STATES OF ELECTRICITY.

THE air, being a non-conductor, muſt be claſſed among electric bodies; and the prime conductor of an electrical machine being ſurrounded with air retains its electric ſtate much better than it would do without that circumſtance. For the electric matter cannot paſs to or from the conductor with the ſame facility as if this impermeable ſubſtance were not interpoſed. H

When air is ſpoken of as impermeable and electric, it muſt not be underſtood as being perfectly ſo, but as being moſtly compoſed of non-conducting parts. There is always moiſture enough in the air to reſtore the natural ſtate to electrified bodies in a few hours. It is likewiſe permeable, as all other electrics are, by the force of the electric matter which divides it or ſeparates its parts: when this happens to a ſolid electric, a hole is made through it. I

Long ſparks are always crooked in various directions, like lightning; which ſeems to be cauſed by the electric matter paſſing through thoſe parts of the air K

in which the beſt conductors are found. Indeed there is reaſon to think that electricity always requires a conductor to enable it to paſs from one body to another. For if a glaſs ſiphon, the legs of which are equal, and reſpectively more than thirty inches long, be filled with boiling mercury, and the ends inverted into baſins likewiſe containing mercury, a double barometer (31, z) will be formed, the upper or arched part of which will be abſolutely void of air. Then if one of the baſins be inſulated and electrified, the electricity will not paſs from the mercury in one leg, through the void, to that in the other; but upon admitting a ſmall bubble of air, it is immediately ſeen paſſing through the vacant ſpace in the form of bright flaſhes or flames. In the vacuum of the air-pump the electric matter will paſs and appear luminous between conductors, however diſtant, forming a beautiful appearance, that very much reſembles the northern lights, or aurora-borealis. But it is found, that in high degrees of exhauſtion the light is leſs, the leſs air is left in the receiver. It ſeems, on conſideration of theſe circumſtances, that the electric matter cannot paſs through the more perfect vacuum, for want of a conductor, but that the conducting part of the air, when introduced, anſwers the purpoſe, while the reſiſtance of the electric part, being very ſmall, on account of the rarefaction, ſuffers it to paſs from one conductor to another, through much greater ſpaces than it can paſs through in the open air.

1. This opinion is ſomewhat more confirmed by the

observation,

obſervation, that the electric matter forces conducting bodies into its path. If a drop of water be laid on the prime conductor, in a poſitive ſtate, very long ſparks may be drawn from it, the drop will aſſume a pointed or conical ſhape, and wet bodies which are held near it: a proof that the water is thrown off. If the ſame experiment be made with melted ſealing-wax, the appearance is very peculiar and amuſing. The ſealing-wax muſt be dropped on or ſtuck to the ſide of the prime conductor, and afterwards melted with a candle; then if the conductor be electrified, either poſitively or negatively, the drop of wax becomes pointed, and ſhoots a number of fine threads into the air, to the diſtance of ſeveral feet. This thread is in the ſame ſtate of electricity as the conductor it iſſues from.

It is remarkable, that the drop of water which M
forms itſelf into a point by electrization does not give the ſpark when negatively electrified. This property is not, however, peculiar to water, but common to all very ſhort pointed conductors that riſe out of another ſurface nearly plane, and of ſome extent. A ſharp metallic point riſing about one thirtieth of an inch out of the ſurface of a ball of three inches diameter, gave ſparks five or ſix inches in length, when poſitive or emitting the electric matter; but the electricity paſſed without ſparks, and with ſcarcely any noiſe, when the point was negative or receiving. This may be a uſeful criterion for diſtinguiſhing the two ſtates.

Fig. 175, repreſents an inſtrument for diſtinguiſh- N
ing the electricities. A and B are two metallic balls,

that may be placed at a greater or less distance from each other by means of the joint at c. The two branches or legs CA, CB, are varnished glass. From one of the balls A, proceeds a short point towards the other ball B. If the two balls be placed in the current or course of the electric matter, so that it may pass through the air from the one to the other, its direction will be known. For if the electric matter pass from A to B, there will be a certain distance of the balls dependant on the strength of the electricity, within which dense sparks will pass from the point; but if its course be in the contrary direction, no spark will be seen, unless the balls be almost in contact, and the point will be tipped with electric light.

## CHAP. IV.

### OF THE ELECTRICITY PRODUCED BY BRINGING A CONDUCTOR NEAR THE ELECTRIFIED PRIME CONDUCTOR: AND OF CHARGING AND DISCHARGING ELECTRIC PLATES.

IF an insulated conductor, free from points, be brought within a certain distance of the prime conductor or cylinder in an electric state, it will also exhibit signs of electricity of the same kind; but if those signs be removed, by taking the spark, and the conductor taken from the prime conductor, it will exhibit signs of the contrary electricity. This is a very remarkable

markable appearance, but may be accounted for, if two suppositions be admitted, viz. first, that the electric matter is attracted by conducting bodies; and secondly, that the parts of the electric matter mutually repel each other, the forces of each power being in a certain inverted ratio of the distance.

For the electric matter, in an insulated and uniform P
conductor, will then be equally diffused through its whole mass, and the attraction which that conductor will exert on any mass of electric matter presented from without, must be the excess of the attractive force of the body over the repulsive force of the electricity it contains. Whence a given conductor will attract the electric matter the most powerfully when the quantity it already possesses is the least possible, and its attractive force will decrease as it becomes more saturated with electricity. Let two equal conductors, composed of like matter, be brought within a small distance of each other, then, if the quantities of electricity they contain be equal, the attractions they mutually exert on those quantities will be equal, and it will remain undisturbed in each body. But if one conductor, A, contain more electricity than the other, B, the attractive power of B will be greatest, and will draw the electric matter from A, till an equilibrium is obtained. It follows also, Q
that in a number of conducting bodies, communicating with each other, the electric matter will be every where of the same density, if the greatest attractive force of the bodies be supposed equal; but if different bodies be supposed to attract the electric matter with

different forces, as is moſt probable, the denſities muſt vary with the forces. This may be called the natural ſtate.

R To apply this to the particular inſtance above recited, ſuppoſe the end of an inſulated conductor to be brought near the prime conductor in a poſitive ſtate, the attractive power of the firſt-mentioned conductor is greater than that of the prime conductor, yet, not being ſufficient to draw ſparks, at the given diſtance, the only effect it can produce is, to make the electric matter accumulate, and become more denſe in that part of the prime conductor, near which it is preſented; by which accumulation the reſt of the prime conductor becomes leſs electrified, as experience teſtifies. This accumulated body of electricity repels, and conſequently rarefies the electric matter naturally contained in that end of the conductor, which is preſented to the prime conductor; the reſt of the fluid becomes more denſe, and the other parts of the conductor which is preſented, exhibit ſigns of electricity; yet, as this conductor in the whole contains no more than its natural quantity, if the electric ſtate be taken off, by drawing the ſpark, and it be afterwards removed from the vicinity of the prime conductor, it becomes negative throughout, by reaſon of the loſs of
S the ſpark. If a conductor be preſented to the prime conductor in a negative ſtate, the effects are reverſed, the attraction being ſtrongeſt at the prime conductor, and the accumulation being in the conductor which is preſented, it exhibits a negative ſtate, which being deſtroyed, upon removal it becomes poſitive, by reaſon

of

of the ſpark which was given to it when apparently negative.

Theſe effects are more conſiderable the leſs the T diſtance is between the two conductors; and the intercedent electric body is peculiarly affected: the manner of which may be better underſtood, by obſerving the phenomena of non-electrics, ſeparated by electrics which are leſs liable to allow the paſſing of the ſpark than the air is.

Upon an inſulated horizontal plate of metal, lay a U plate of glaſs, conſiderably larger, ſo that there may be a rim of three or four inches projecting beyond the metal on every ſide. Upon the glaſs lay another plate of metal, of the ſame ſize as the former, ſo as preciſely to cover it. Electrify the upper plate, and the lower will exhibit ſigns of electricity. Continue the electrization, and the lower plate will emit ſparks to an uninſulated body for a time, and afterwards ceaſe. Separate the plates from the glaſs without uninſulating them, and the glaſs will appear to be poſſeſſed of the contrary electricities on the oppoſite ſides. That ſide which communicated with the prime conductor, during the electrization, will have a like electricity, and the other the contrary. Take off the electricity of the plates of metal, and carefully replace the glaſs on the lower, without deſtroying the inſulation, and alſo replace the upper plate with the ſame precaution. Then, with one end of an inſulated wire, not pointed, but knobbed at the ends, touch one of the plates, and bring the other end near the other plate: the conſequence will be, that a ſtrong and loud ſpark will paſs between

it and the wire, the electricity of the glass will be discharged, and the plates and the wire will exhibit few or no signs of electricity.

v An electric body, the surfaces of which are thus possessed of the contrary electricities, is said to be charged. The insulation of the lower metallic plate and of the discharging wire is not necessary, except for the purpose of drawing inferences, respecting the manner of charging the electric plate. If the electricity of the prime conductor be strong, and the glass thick, the discharge will often be made by a spark from the one metallic plate to the other, over the surface of the glass which projects on every side; but if the glass plate be thin, in which case, at an equal intensity, it admits of a much greater charge, the discharge will be made through its substance. Glass, as thick as one eighth of an inch, may be penetrated by this means, one or more holes being made where the electric matter has passed, in which holes the glass is pulverized, and may be picked out with a pin.

w The greater the surface of the glass, the greater charge it will contain, the same intensity being supposed. But a given machine will not superinduce so strong an electric state on a large plate as on a small one; the reason of which seems to depend on the different intervals of time required in the charging, conjoined with the different magnitudes of the surfaces at which the electricity is communicated to the air. If there were no escape of the electric matter during the time of charging, the times would probably

be

be as the ſurfaces of the plates, equal thickneſſes being always ſuppoſed; and if two plates were equally charged, the eſcape would perhaps be likewiſe as the ſurfaces. Theſe being premiſed, the whole eſcape x
would be as the time of charging, and the ſurfaces of each conjointly, that is, becauſe the times are as the ſurfaces, in the duplicate ratio of their ſurfaces directly. Hence it appears that the eſcape in plates, that increaſe in ſize, approaches rapidly and continually nearer to the quantity of electricity ſupplied by the machine, and that the more powerful machine, by diminiſhing the time of charging, will charge higher in the inverſe proportion of the time. It muſt be confeſſed that the ſuppoſitions not being accurate, the proportions are only nearly true, yet this way of conſidering the ſubject may ſerve to indicate the cauſes, though not ſtrictly to meaſure the effect.

From the experiment (297, u) of ſeparating the glaſs y
from the plates of metal, it is ſhewn, that the ſurplus of the electricity on one ſurface, is either accurately or very nearly equal to the deficiency on the other; for if it were otherwiſe, the plates and the diſcharging wire would become ſtrongly poſſeſſed of the predominating electricity. It alſo follows, that if z
the theory of poſitive and negative electricity be true, electric bodies muſt contain the electric matter, for the electric ſtates are evidently on the ſurfaces of the glaſs, independent of the metal. Now, though it may eaſily be underſtood that a poſitive ſtate may be ſuperinduced by an accumulation of electricity on one ſurface, yet it is abſurd to ſuppoſe that the electric matter

can be emitted and exhausted from the other side, if it did not exist there, previous to such emission and exhaustion. From this circumstance it may be concluded, according to the same theory, that all bodies, as well electrics as non-electrics, attract the electric matter, but that electrics, being so constructed as not to admit it into their substance, as non-electrics do, must condense it upon their surfaces, and at all times hold a great quantity so condensed. And if the quantity of electricity be increased or diminished on one side, the electricity on the other surface must be rarefied or condensed, in consequence of the diminution or increase of the whole attractive force of the body. The effects will also be more considerable the less the distance is between the two surfaces (295; o).

A It is not possible to charge an electric plate by inducing an electric state on one of its surfaces, unless the other be at the same time sufficiently near to a non-electric to assume the contrary state by emitting or receiving the electric matter.

B If a plate of glass be laid upon an uninsulated plate of metal, the upper surface may be rendered electric by friction, or by applying an electrified body successively to its parts. This electricity may be taken off by touching the upper surface with an uninsulated metallic plate of the same dimensions as that upon which the glass is placed, but will not be entirely taken off, because the communication between the two surfaces in this method is not perfect, and because the metal cannot by ordinary means, be brought into actual contact with the glass. The small quantity which remains,

remains, produces an effect which has been miſtaken for a perpetual electricity. For if a plate of metal, to which a glaſs handle is affixed, be laid upon the glaſs, this ſmall quantity of electricity will influence the metal, and, without actually communicating the electric matter, will cauſe it to exhibit a ſimilar ſtate (297). If this be taken off, by drawing the ſpark, and the metal then removed, by means of the glaſs handle, it will be found poſſeſſed of the contrary ſtate of electricity, and another ſpark may be obtained. The metallic plate may be then again applied to the ſurface of the glaſs, and the proceſs again repeated, and ſo on for a prodigious number of times, without any ſenſible difference in the event. For the electricity at the ſurface of the glaſs being almoſt in the natural ſtate, as to condenſation, does not diſappear for a very long time, and the very near approach of the metal enables it to produce the ſame effect as would be obtained at a greater diſtance from a ſtronger electricity (295, 0). This is made obvious, by bringing the metallic plate near the ſurface of the glaſs before its firſt ſtrong electricity is taken off, for the ſame event is then perceived at the diſtance of four, five, or ſix inches, as in the former caſe is produced by contact.

The vapours of the atmoſphere are continually attaching themſelves to the ſurface of cold glaſs, and by that means deſtroy the electricity. Sulphur, wax, or reſin, being leſs ſubject to this, retain their electric ſtate much longer. A plate of glaſs or wood, coated over with any ſubſtance of this nature, may be excited

by

by friction, and will produce electricity in a metallic plate, in the manner above deſcribed, for a very great length of time. Such a plate, together with its metal, has been named the electrophorus, fig. 177.

E If the diſcharge of an electrified plate be made by the parts of a living animal, a conſiderable pain will be felt chiefly at the extremities of the muſcles. For example, if the lower metallic plate be touched with one hand, and the other brought to the upper plate, at the inſtant of the emiſſion, a pain will be felt at the wriſts and elbows, which as inſtantly vaniſhes. If a larger glaſs plate be uſed, the pain will be felt in the breaſt; if yet larger, the ſenſation will be that of a univerſal blow. This ſenſation has obtained the name of the ſhock, and will deprive animals of life, if ſufficiently ſtrong. The ſhock from 30 ſquare inches of glaſs, well charged, will inſtantly kill mice, ſparrows, or other ſmall animals. Six ſquare feet of glaſs will deprive a man of ſenſation for a time, if the head be made a part of the circuit through which the electricity moves. No inconvenience has been found from the electric ſhock by men of ſtrong habits, but women of delicate conſtitutions have had convulſions from a
F violent ſhock. It may be obſerved, that the electric ſhock is a proof that the electric matter can paſs through the ſubſtance of non-electrics, and is not univerſally conducted along their ſurfaces alone, as ſome have ſuppoſed.

CHAP.

# CHAP. V.

## OF ELECTRIC JARS; THE VELOCITY OF THE SHOCK; LIGHT IN THE BOYLEAN VACUUM; THE CHARGING A PLATE OF AIR, WHENCE IS DEDUCED THE ACTION OF POINTED BODIES.

FOR the ſake of ſimplicity and preciſion, the effects of electricity, in charging glaſs, have been deſcribed as they happen in flat pieces or plates. Theſe, however, are ſeldom uſed. The object of the philoſopher, in general, is to collect a large quantity of electricity, by means of the ſurfaces of electrics, and it is neither neceſſary nor convenient to uſe flat plates. He therefore accommodates himſelf with a ſufficient number of prepared jars. Theſe are made of various ſhapes and magnitudes, but the moſt uſeful are thin cylindrical glaſs veſſels, about four inches in diameter, and fourteen in height; coated within and without, with tin-foil, which is ſtuck on with gum-water, paſte, or wax, excepting two inches of the rim or edge, which is left bare, to prevent the communication between the coatings. About four inches from the bottom, within, is a large cork, that receives a thick wire, ending in ſeveral ramifications, which touch the inſide coating; the upper end of the wire terminating with a knob, conſiderably above the mouth of the jar, Fig. 179. When it is required to be charged, it may be held

in the hand, or placed on an uninſulated table, and the knob of the wire applied to the conductor; the inſide coated ſurface becomes poſſeſſed of the electricity of the conductor, and the external ſurface acquires the contrary electricity, by means of its uninſulated coating. When a jar of this kind is highly charged, it will diſcharge ſpontaneouſly over the uncoated ſurface, and ſeldom through the glaſs, whereas, when the uncoated ſurface is large, it is more apt to break by that means, and become uſeleſs. Yet, there is no certainty that a jar, which has diſcharged itſelf over its ſurface, will not at another time break by a diſcharge through the glaſs, as the contrary often happens. If paper covered with tin-foil be uſed for the coating, with the paper next the glaſs, the jar will be leſs liable to break.

A jar of conſiderable thickneſs, with a neck like a bottle, in which is cemented a thick tube to receive the wire, will ſuſtain a very high charge, and produce much greater effects than one of the laſt deſcription. The charging wire being inſerted looſely into the tube, will fall out on inverting the jar, and the charge will remain for ſeveral weeks without much loſs. A jar thus charged, may be put into the pocket, and applied to many purpoſes that the common jar cannot be uſed for.

If the inſide of the jar be conſiderably damped, by blowing into it, through a tube reaching to the bottom, it will take a charge nearly one third greater than in the ordinary ſtate.

When a greater degree of electric force is required, larger

larger jars muſt be uſed, in which the form is of no conſequence, except as far as relates to convenience. But it is leſs expenſive, and nearly as effectual, to uſe a number of ſmaller jars, having the ſame quantity of coated ſurface as the large jars. In this caſe, a communication muſt be formed between all the outſide coatings, which may be done by placing them on a ſtand of metal; and alſo between all the inner coatings, which is beſt done by means of wires. Such a collection is called a battery, and may be charged and diſcharged like a ſingle jar.

In diſcharging electrical jars, the electricity goes in M
the greateſt quantity through the beſt conductors, and by the ſhorteſt courſe. Thus, if a chain and a wire, communicating with the outer coating, be preſented to the knob of a jar, the greater part of the charge will paſs by the wire, and very little by the chain, which is a worſe conductor, by reaſon of its diſcontinuation at every link. When the diſcharge is made by the chain only, ſparks are ſeen at every link, which is a proof that they are not in contact; and as the chain muſt be ſtretched by a conſiderable force before the ſparks ceaſe to appear on the diſcharge, it follows that there N
is a repulſive power in bodies, by which they are prevented from coming into contact, unleſs by force, as has been obſerved in the former part of this treatiſe (I. 14, A; I. 48, A, B).

By accurate experiments it appears, that the force O
of the electric ſhock is weakened, that is, its effects are diminiſhed, by uſing a conductor of great length in making the diſcharge. Yet, a very conſiderable ſhock

was given by the Abbé Nollet, in the preſence of the French King, to one hundred and eighty men; the firſt of whom formed a communication with the outer coating, the reſt joining hands in a circular line, and the laſt touched the knob of the inner coating. They were all ſhocked at the ſame inſtant. Dr. Watſon, and many other gentlemen of eminence in the philoſophical world, were at the pains of making experiments of the ſame kind, but much more accurate.
P They found, by means of wire inſulated on baked wood, that the electric ſhock was tranſmitted inſtantaneouſly through the length of 12276 feet.

Q When any animal or ſubſtance is to be ſubjected to the ſhock, it is uſually done by means of two chains, one of which connects one extremity of the animal or ſubſtance with the outer coating, and the other being faſtened to, or laid on, the other extremity, is applied to the knob of the inner coating to make the diſcharge. The animal or ſubſtance thus forming a part of the
R circuit, receives the whole ſhock. The ſtrong ſhock of a battery will melt wire of the ſeventieth of an inch in diameter, and wires of leſs diameters are frequently blown away, and diſperſed: and the effect is the ſame with equal quantities of electricity, whether the intenſity be greater or leſs, within certain extended limits.
S Gunpowder may be fired by a charge of three ſquare feet: the method is, to put it into a quill, and thruſt a wire into each end, ſo as not to meet, and then make theſe wires a part of the circuit. A leſs charge will ſerve if iron filings be mixed with the gunpowder.
T Spirit of wine, ether, or a mixture of common and

inflam-

inflammable air, may alſo be fired by the ſame means, or even by the ſpark from the conductor. Yet it ſeems probable in theſe caſes, that inflammation does not take place becauſe the electric matter is fire, or in an ignited ſtate, but becauſe its extreme velocity excites that inteſtine motion which raiſes the temperature of bodies (121, C, D, E).

If the ball of a thermometer be placed in a ſtrong u
current of electricity, the mercury or ſpirit will riſe many degrees*.

A ſtrong ſhock gives polarity to ſmall needles. v

Electricity will paſs by means of non-electrics that w
are ſo ſmall as to be deſtroyed by its paſſage, as has juſt been inſtanced in wires: the force of the exploſion in theſe inſtances is very conſiderable, and is termed the lateral force of electricity. The following is a proof of this, and may be exhibited with leſs than a ſquare foot of coated glaſs, if well charged. At the x
glaſs-houſe there is uſually a great number of ſolid ſticks of glaſs, about a quarter of an inch diameter; if theſe be examined narrowly, ſeveral of them will be found to be tubular for a conſiderable length, but the diameter of the cavity ſeldom exceeds the 200th part of an inch. Select theſe, and break off the tubular part, which may be filled with quickſilver by ſucking; care being taken that no wet previouſly inſinuates itſelf, and then ſend the ſhock through this ſmall thread

* From 67 to 99 degrees, in a ſmall mercurial thermometer. See Nairne's Deſcription of his Electrical Machine. London, 1783.

of quickfilver, which will inftantly be difploded, and will break or fplit the tube in a curious manner.

Y If a piece of the common glafs tube be drawn out very fmall, by means of the blow-pipe, and then filled with mercury, the fhock will caufe both the mercury and the tube to difappear in the explofion; nothing being feen but fmoke or vapour.

Z An experiment fimilar to thefe may be made with a glafs-tube filled with water. Take a fmall glafs-tube, the cavity of which is about a quarter of an inch in diameter, fill it with water, and ftop the end with foft pomatum: through the pomatum infert two wires, that they may almoft touch each other, and make their ends a part of the circuit in the difcharge of a ftrong fhock, from about two feet fquare of coated glafs; the confequence will be, that the water will be difperfed in every direction, and the tube blown to pieces, particularly in the middle, near the difcontinuation of the wire: the ends with the wires and pomatum will fometimes be found undifturbed. This is a ftriking inftance of the velocity and force with which the electric matter is moved (I. 40).

A This property, of being charged and difcharged, is not peculiar to glafs, but is common to all other electrics.

B If a thin bottle be exhaufted of air by means of the air-pump, it will receive a confiderable charge by applying its bottom to the electrified prime conductor, during which time the electric matter will pafs through the vacuum between the hand and the inner furface of that part of the glafs which is neareft the prime conductor.

ductor. This appearance, the cause of which has B
already been in some degree explained (292, K) is exceedingly beautiful in the dark, especially if the bottle be of a considerable length. It exactly resembles those lights which appear in the northern sky, and are called streamers, or the aurora borealis. If one hand be applied to the part of the bottle which was applied to the conductor, while the other remains at the neck, the shock will be felt, at which instant the natural state of the inner surface is restored by a flash, which is seen pervading the vacuum between the two hands.

The electric shock may be given from a plate of C
air, by means of two large plates of metal, or rather boards covered with tinfoil; one of which is to be suspended to the prime conductor, and the other placed parallel to it on an uninsulated stand, at a convenient distance. These boards may be regarded as the coatings of the plate of air contained between them, and if a communication be formed between them, by touching the uninsulated board with one hand, and applying the other hand to the conductor, the shock will be felt accordingly. It is almost unnecessary to observe, that if the electricity be powerful, or the distance between the plates small, the charge will pass from the one to the other in a spark through the air.

If we compare this experiment with what has al- D
ready been observed respecting the charging and discharging electric bodies, it will appear that most of the electric phenomena are the consequences of the air being charged. Thus, the prime conductor imparts its electricity to the surface of air immediately contigu-

ous, and when the ſpark is drawn the diſcharge is made to the non-electrics, namely, the floor and wainſcot of the room, which are in contact with the oppoſite ſurface. The charge of electrics has already been obſerved to be greater, (297, T) the nearer the ſurfaces are to each other; thus, glaſs beyond half an inch thickneſs can ſcarcely be charged by our machines: in
F like manner, the diſcharge, that is to ſay, the ſpark from the conductor, will be greater, when a large company ſtand about it than at other times, the body of air which is interpoſed between the conductor and the neareſt uninſulated non-electrics being then leſs in thickneſs than at other times. It follows alſo, that a large conductor will give a larger ſpark than a leſs; the diſcharge being from a ſurface proportionally greater. And ſince this diſcharge conſiſts chiefly of the electric matter, reſiding at, or near the ſurface of contact, and little, if at all, of that which may be within the ſubſtance of the conductor, it is of no con-
G ſequence whether the conductor be a ſolid non-electric or hollow, provided the ſurface be unaltered in form and magnitude. Hollow cylinders of copper, or tin, or wood, or paſteboard, covered with tinfoil, or ſtrongly gilt, are the conductors generally in uſe.

H It is a conſequence of the air being charged that broad non-electric ſurfaces draw large ſparks from the conductor; for the ſparks are the diſcharges of a large plate of interpoſed air. A leſs ſurface will draw a leſs ſpark, but becauſe the ſame machine charges leſs ſurfaces higher than greater, the ſpontaneous diſcharge through the body of the electric air will be

made

made at a greater diſtance of the ſurfaces, that is to ſay, the ſparks will be longer. If the ſurface of the non-electric preſented be yet leſs, the ſparks, for the ſame reaſon, will be leſs, and emitted to a ſtill greater diſtance. And if the ſurface be indefinitely ſmall, or, in other words, if the non-electric be pointed, the ſpark may be ſo ſmall as to be inviſible, and the diſtance to which it can be emitted may be unlimited. The effect of pointed bodies ſeems to depend on cir- I
cumſtances of this nature; but the reaſon of the different appearances of the light on points electrified poſitively or negatively, ſtill remains a difficulty.

## CHAP. VI.

### AN ACCOUNT OF SEVERAL INSTRUMENTS, AND OF THE PRODUCING AN ELECTRIC STATE WITHOUT EVIDENT FRICTION.

THE condenſer is an inſtrument of the ſame kind K
as the electrophorus, but differently uſed. For inſtead of the interpoſed electric being previouſly charged, it is of great importance here, that it ſhould be perfectly in the natural ſtate. In this ſituation if the upper conducting plate be connected with a larger body weakly electrified, while the lower plate is uninſulated, the upper will receive the electric ſtate, and on being ſeparated or lifted up, will exhibit it with a much

higher degree of intensity. So that very small degrees of electricity may be rendered sensible by this admirable contrivance.

L To explain the cause of this, it must be recollected that the action of a neighbouring conductor (295, P) diminishes the intensity of the electric state in another conductor, more especially if the former be uninsulated. The electrified insulated conductor will therefore admit of a more considerable degree of electrization before its intensity can be rendered equal to what it was when solitary. Suppose this done, and the additional conductor then removed, and it is evident that the electrified conductor will, by the uniform diffusion of the electricity, be left in a higher state of electrization than it would have acquired by the same means without the

M assistance of the uninsulated conductor. The two plates of the condenser are in these circumstances: the upper receives more electricity, because of the vicinity of the lower, and shews a greater intensity when removed out of that vicinity.

N To accomplish this purpose, in the most effectual manner, it is necessary that the interposed electric be very thin (297, T) and that the surfaces be well adapted to each other. The electric may be a coat of varnish laid on the lower or upper plate, or a thin silk fastened to the surface of the upper.

O If the electricity be strong enough to charge the electric, the acquisition of the electric state by the metal will be counteracted on the electrophorus principle, and the charge will tend greatly to disturb and falsify the results of experiments made while it remains.

A slight

A flight warming of the varnifh, either by the fun or any other gentle heat, will however diffipate it. But the beft remedy for this, is to ufe fuch an apparatus as will neither retain a charge nor fuffer the metallic plate to obtain a higher electric ftate than it can carry off on its feparation.

The fagacious inventor has therefore fubftituted inftead of the lower or fixed part of the apparatus, a piece of dry marble, or marble varnifhed with copal varnifh and kept in an oven for a fhort time, or very dry wood. Here the very thin ftratum of air between the metal plate and the fubftance it refts on, feems to fupply the place of the electric, and the imperfectly conducting power of the marble or the wood, prevents any charge from being accumulated. This laft apparatus alfo performs its office better than the other.

To ufe this inftrument the metallic plate is to be laid on the marble or varnifhed metal, and a connection formed between the upper plate and the body, the electricity of which is to be examined. This connection may remain eight or ten minutes, or longer, if the electricity be very weak, and then be removed. The metal plate being lifted up, will exhibit figns of electricity if the connected body were in an electric ftate *.

* The electrophorus and condenfer were invented by Mr. Alexander Volta, Profeffor of Experimental Philofophy at Como, &c. This laft inftrument is honourable to its inventor, not only on account of the extenfively ufeful purpofes to which it has been and may be applied; but likewife becaufe it was difcovered, not cafually, like moft other electrical apparatus, but in confequence of fcientific deduction and reafoning. See Phil. Tranf. Vol. 72, Part 1, or Cavallo's Electricity.

Various

R Various instruments have been contrived to discover the presence of electricity, together with its intensity and kind. These have been adapted to observe either the attraction, or repulsion, or the length and figure of the spark.

S Small degrees of electricity are very well shewn by the divergence of two fine hempen threads, suspended
T together from the conductor. If little balls of pith or cork be fastened to the ends of the threads, they will serve to denote still greater intensities, as they will not so soon arrive at their utmost divergence by the mutual re-
U pulsion. Fig. 184, is a very useful electrometer upon this principle. It consists of an upright stick of box-wood, A B, on one side of which is affixed a graduated semicircle; [illegible] is a ball of pith or cork, and is stuck upon the end of a small rod or radius of wood, which, by means of a small axis at C, is moveable in a plane parallel to that of the semicircle. This electrometer is fixed upright on the prime conductor; the radius will therefore hang perpendicularly down when it is not electrified; and according to the intensity of the electric state given to the conductor, the repulsion must cause the ball to ascend. The ascent will be marked by the graduations.

V This electrometer, though very useful, has the imperfection of being less sensible of the changes of electricity when the intensity is considerable, than when the repulsion at the beginning of the scale acts at right angles to the radius. It has also another inconvenience common to all electrometers, namely, the want of a standard of original adjustment, by means of which all instru-

ments of the kind may indicate the ſame intenſity in ſimilar circumſtances.

Fig. 174 repreſents an electrometer for meaſuring the length of the ſpark. A repreſents a ſection of the prime conductor; the wooden ſtem B being inſerted therein. The bent part D is varniſhed glaſs. Through a wooden collar C paſſes a wire that carries a ball of metal E, which may be ſet at different diſtances as required. A chain may be hung on the outer part F. This electrometer is chiefly uſeful for ſhocks, greater or leſs as may be required. For this purpoſe the knob of the jar muſt be in contact with the prime conductor and a chain from F muſt touch the external coating. When the charge is ſufficiently high, the exploſion will be made through the interval between A and E.

Fig. 178. is a very ſenſible electrometer, well adapted for the obſervation of the preſence and quality of either natural or artificial electricity. A B C is the braſs caſe containing the inſtrument. When the part A B is unſcrewed and the electrometer taken out, it appears as repreſented at A B D C. A glaſs tube C D N M is cemented into the piece A B. The upper part of the tube is ſhaped tapering to a ſmall extremity, which is entirely covered with ſealing-wax. Into this tapering part a ſmall tube of glaſs is cemented; the lower extremity being alſo covered with ſealing-wax, projects a ſmall way within the tube C D M N. Into this ſmaller tube a wire is cemented, which, with its under extremity, touches a flat piece of ivory H, faſtened to the tube by means of a cork. The upper extremity of the wire projects about a quarter of an inch above the tube,

tube, and ſcrews into the braſs cap E F, which cap is open at the bottom, and ſerves to defend the waxed part of the inſtrument from the rain, &c. From H are hung two fine ſilver wires, having very ſmall corks at their lower ends, which by their repulſion ſhew the electricity. I M and K N are two ſlips of tin-foil ſtuck to the inſide of the glaſs, and communicating with the braſs bottom A B. They ſerve to convey away that electricity, which, when the corks touch the glaſs, is communicated to it and might diſturb their free motion.

Y To uſe this inſtrument for artificial electricity, bring a body in an electric ſtate (a ſtick of ſealing-wax previouſly rubbed, is as convenient as any) near the braſs cap; the corks (294, O) will diverge with the ſame electricity till one of them touches the tinfoil I M or K N when they will immediately collapſe. Remove the electrified body, and the corks will again diverge with the contrary electricity. In this ſituation, ſuppoſing ſealing-wax to have been uſed, a body poſſeſſed of the poſitive electricity being brought near the cap will cauſe the corks to diverge ſtill more; but if negative, it will cauſe them to approach nearer to each other.

Z When this electrometer is to be uſed to try the electricity of fogs, air, clouds, &c. the obſerver is to do nothing more than to unſcrew it from its caſe and hold it by the bottom A B, to preſent it to the air in an open place a little above his head, ſo that he may conveniently ſee the corks P. A very ſmall degree of electricity will cauſe them to diverge, and its quality may be

be aſcertained by bringing an excited ſtick of ſealing-wax, or other electric, towards the cap E F.

But the electrometer of Bennet, is by far the moſt delicate of any of the inſtruments which have yet been applied for diſtinguiſhing ſimple electricities.

It conſiſts of two ſlips of leaf gold, A A, fig. 180, ſuſpended in a glaſs B. The foot C may be made of wood or metal; the cap D of metal. The cap is made flat on the top, that plates, books, evaporating water, or other things to be electrified, may be conveniently placed upon it. The cap is about an inch wider in diameter than the glaſs, and its rim about three quarters of an inch broad, which hangs parallel to the glaſs, to turn off the rain and keep it ſufficiently inſulated. Within this is another circular rim, about half as broad as the other, which is lined with ſilk or velvet, and fits cloſe upon the outſide of the glaſs: thus the cap fits well, and may be eaſily taken off to repair any accident happening to the leaf gold. Within this rim is a tin tube E, hanging from the centre of the cap, ſomewhat longer than the depth of the inner rim. In the tube a ſmall peg is placed, and may be occaſionally taken out. To the peg, which is made round at one end and flat at the other, two ſlips of leaf gold are faſtened with paſte, gum-water, or varniſh. Theſe ſlips, ſuſpended by the peg, and that in the tube faſt to the centre of the cap, hang in the middle of the glaſs, about three inches long, and a quarter of an inch broad. In one ſide of the cap there is a ſmall tube G, to place wires in. It is evident, that without the glaſs the leaf gold would be ſo agitated by the leaſt motion of the air, that it would be uſeleſs; and

and if the electricity should be communicated to the surface of the glass, it would interfere with the repulsion of the leaf gold; therefore two long pieces H H of tin foil are fastened with varnish on opposite sides of the internal surface of the glass, where the leaf gold may be expected to strike, and in connection with the foot. The upper end of the glass is covered and lined with sealing wax as low as the outermost rim, to make its insulation more perfect*.

The sensibility of this instrument is so great as even to astonish the most experienced electricians who have not before been witnesses to its effects. The brush of a feather, the projection of chalk, hair-powder or dust against its cap evince strong signs of electricity. The electricity of vapour is elegantly shewn by pouring a tea-spoonful of water on an agitated coal placed in a metallic cup upon the cap of this electrometer: and a very great and pleasing variety of other experiments may be made with this excellent instrument.

A The ingenious electrician who is not provided with the instruments here described, may supply their place by contrivances which a knowledge of the general facts will easily indicate. Strong electricities may be distinguished by the light at the extremities of pointed bodies, and for less intensities a downy feather may be suspended by a fine thread of silk. This being electrified, by bringing it into contact with the cylinder or conductor of a machine, will preserve its electric state for a considerable time; during which it will be repelled

* Phil. Transf. vol. 74. p. 27.

by

by bodies in the same state, and attracted by all others.

We shall finish this general account of artificial B
electricity with pointing out some of the other means of producing it, which do not seem referable to the usual method of excitation.

The escape of vapor or elastic fluid from bodies C
in a state of combustion, from water thrown on hot coals, or from chemical menstrua in a state of effervescence, leaves the residue negatively electrified. These important facts seem to point at a general law of electricity, that may tend in future to explain the phenomena in which heat is latent (117, T), and to which it bears a striking analogy *.

It appears to be a fair deduction from these facts, D
that as bodies take up electricity when they assume an elastic form, so they must deposit it when they are again condensed. The experiments, however, to ascertain this have not yet been made.

Sulphur melted in an earthen vessel, and placed to E
cool upon uninsulated conductors, is strongly electric when taken out, but is not so when it has stood to cool upon electric substances.

Sulphur melted in a glass vessel acquires a strong F
electricity in the circumstances above mentioned, whether the vessel be placed on electrics or not; but stronger in the former case. This electricity is yet stronger, if the glass be coated with metal. In these cases the glass is always positive, and the sulphur negative. It is particularly remarkable, that the sulphur

* The discovery of Sig. Volta. See Phil. Transf. vol. 72.

acquires no electricity till it begins to cool and contract, and is the ſtrongeſt at the time of the greateſt contraction: whereas the electricity of the glaſs is at that time weakeſt, and is the ſtrongeſt of all when the ſulphur is ſhaken out before it begins to contract, or has acquired any negative electricity*.

G It has been obſerved, that ſilk or worſted ſtockings become electrical after being worn ſome hours, more particularly the ſilk, as does alſo a beaver ſhirt worn between two others. If a white and a black ſilk ſtocking be worn on the ſame leg, they obtain contrary electricities. When drawn off together they ſhew very little ſigns of electricity, but, upon ſeparating them, each indicates an electrical ſtate ſo ſtrongly, that the repulſion inflates them, ſo as to exhibit the intire ſhape of the leg. If the two ſtockings be allowed to come together, they ſtrongly attract each other, the inflation ſubſides, and they ſtick very cloſely together; in which ſituation they retain their electric ſtate, notwithſtanding the approach of the ſharpeſt metallic point. A ſecond ſeparation again exhibits their reſpective electricities as before; and this may be done ſeveral times without much diminiſhing their electricities. The electricity of the black ſtocking is negative, and of the white poſitive.

H The tourmalin is a hard gem, either pellucid or opake, of a red colour, and is brought from the iſland of Ceylon, by the Dutch. It poſſeſſes the property of aſſuming an electric ſtate if heated; one ſide of it be-

* Theſe facts are denied by Volta, in Phil. Tranſ. vol. 72.

coming

coming positive, and the other negative. If this electric state be taken off by contact, the stone will become electric as it cools; but with this difference, that the side, which during the heating was positive, will now be negative, and the other side positive, which before was negative. But if the electric state be not taken off, the same kind of electricity will be found on the same side during the whole time of heating and cooling. Either side of the tourmalin will become positive by friction, and both may be made so at the same time.

These are the chief properties of this very remarkable stone, which are also common to the Brazil topaz, and some other gems. There are several important particulars relative to this and every other branch of electrical knowledge, which cannot be enumerated and described, in an introductory book, on account of the great length of detail they would require. For these, the student must have recourse to treatises written expressly on this subject. There are also a number of fanciful and pleasing variations of the common experiments. Bells are rung by an insulated clapper, which is alternately attracted and repelled between two bells in opposite states of electricity; figures cut in paper are made to dance by the attraction and repulsion between two metallic plates; light mills of pasteboard are driven round by the current of air from electrified points, &c. particular accounts of all which may be had in pamphlets, which are frequently sold by the makers of the electrical apparatus *.

* For a fuller account of electrical discoveries and apparatus, consult Priestley's History of Electricity; Adams's Essay on Electricity; or Cavallo's Complete Treatise.

## CHAP. VII.

### OF NATURAL ELECTRICITY; AND OF THE IDENTITY OF LIGHTNING AND THE ELECTRIC MATTER.

k THAT electricity is no trivial or confined ſubject, muſt appear from what has already been ſaid, ſince there is no body in nature that is not acted upon by it, either as a conductor or non-conductor. The importance of the electric matter in the ſyſtem of the world is more particularly confirmed by obſervations on thoſe phenomena, which take place without the concurrent operation of man. Of theſe it will be proper to give ſome account.

L Several fiſhes poſſeſs the property of giving the electric ſhock. The torpedo, or numbing fiſh, and one or more ſpecies of eels from Surinam, if touched by the hand, a metal rod, or any other conductor, give a conſiderable ſhock to the arm, but may be ſafely touched by means of a ſtick of ſealing-wax. The ſhock depends on the will of the fiſh, and is tranſmitted to a great diſtance, ſo that if perſons in a ſhip happen to dip their fingers or feet in the ſea, when the fiſh is ſwimming at the diſtance of fifteen feet, they are affected by it.

M Many diſorders of the human frame have been cured or relieved by electricity. In all caſes, except thoſe called nervous, the electric wind from a wooden or

metallic

metallic point, the ſpark, or gentle ſhocks may be ſafely adminiſtered without fear of doing harm, if no good effect ſhould be produced. This remedy ſeems peculiarly applicable to local diſorders, ſuch as ſwellings, contractions, rheumatic and other pains, palſies, &c. in which its effects are very often wonderfully ſudden and beneficial. The ſpark or ſmall ſhocks through the pelvis, regulated according to the feelings of the patient, are ſaid to be an infallible cure for the ſuppreſſion of the catamenia; and it is certain that in many deplorable caſes it has effected a cure. It is generally admitted as a rule in the application of electricity, that it ought never to be ſo ſtrong as to be diſagreeable to the patient in any conſiderable degree.

But the moſt remarkable appearances of electricity, which are viewed with ſurpriſe and admiration by all ranks of people, are thoſe which may be termed atmoſpherical, as for the moſt part exiſting in, or depending on, the ſtate of the atmoſphere. Lightning is proved to be an electric phenomenon, and there is little doubt but the aurora-borealis, whirlwinds, water-ſpouts, and earthquakes, depend on the ſame principle.

The reſemblance between the electric ſpark and lightning, is ſo obvious, that we find it among the earlieſt obſervations on the ſubject; but the proof of the important theorem of their identity was reſerved for Dr. Franklin, who is ſo juſtly celebrated for his many diſcoveries in this branch of natural philoſophy. He firſt obſerved the power of uninſulated points, in drawing off the electricity from bodies at great diſtances, and thence inferred that a pointed metallic bar, if inſulated at a conſiderable height in the air, would

become electrical by communication from the clouds during a thunder-ſtorm. He communicated this thought to the public; and ſeveral machines, conſiſting of inſulated iron bars, erected perpendicular to the horizon, and pointed at top, were ſet up in different parts of France and England. The firſt apparatus that was favored with a viſit from this ethereal matter, was that of Monſ. Dalibard, at Marly la Ville, about ſix leagues from Paris. It conſiſted of a bar of the length of forty feet, and was electrified on the tenth of May, 1752, for the ſpace of half an hour, during which time the longeſt ſparks it emitted meaſured about two inches.

Dr. Franklin, after having publiſhed the method of verifying his hypotheſis concerning the ſameneſs of electricity with the matter of lightning, was waiting for the erection of a ſpire in Philadelphia to carry his views into execution; not imagining that a pointed rod of a moderate height could anſwer the purpoſe; when it occurred to him, that by means of a common kite he could have a readier and better acceſs to the regions of thunder, than by any ſpire whatever. Preparing therefore a large ſilk handkerchief, and two croſs ſticks of a proper length, on which to extend it, he took the opportunity of the firſt approaching thunder-ſtorm, to walk into a field in which there was a ſhed convenient for his purpoſe. But, dreading the ridicule which too commonly attends unſucceſsful attempts in ſcience, he communicated his intended experiment to nobody but his ſon, who aſſiſted him in raiſing the kite.

The

The kite being raised, the end of the string being tied to a silk string, which he held in his hand, and a small key being fastened at the place of junction, a considerable time elapsed before there was any appearance of its being electrified. One very promising cloud had passed over it without any effect; when, at length, just as he was beginning to despair of his contrivance, he observed some loose threads of the hempen string to stand erect, and to avoid one another just as if they had been suspended on a common conductor. Struck with this promising appearance, he immediately presented his knuckle to the key, and, let the reader judge of the exquisite pleasure he felt at the moment, the discovery was complete. He perceived a very evident electric spark. Others succeeded, even before the string was wet, so as to put the matter past all dispute; and when the rain had wetted the string, he collected the electricity very copiously. This happened in June 1752, a month after the electricians in France had verified the same theory, but before he had heard of any thing they had done. R

The grand practical use which the Doctor made of this discovery, was to secure buildings from being damaged by lightning, a thing of vast consequence in all parts of the world, but more especially in several parts of North America, where thunder-storms are more frequent, and their effects, in that dry air, more dreadful, than they are ever known to be with us. S

This great end is accomplished by so easy a method, and by so cheap and seemingly trifling apparatus, as fixing a pointed metalline rod higher than any part of the T

building, and communicating with the ground, or rather the neareſt water. This wire the lightning is ſure to ſeize upon, preferably to any other part of the building, unleſs it be very large and extended, in which caſe wires may be erected at each extremity; by which means this dangerous power is ſafely conducted to the earth, and diſſipated without doing any harm to the building.

Conducting rods are now become very common, both for the purpoſe of ſecuring buildings, and of making obſervations on the ſtate of the atmoſphere. The beſt of thoſe which are intended for the latter purpoſe, is the following. On the top of any building, which will be the more convenient if it ſtand upon an eminence, erect a pole as tall as a man can manage without difficulty, having on the top of it a ſolid piece of glaſs or baked-wood, a foot in length. Let this be covered with a tin or copper veſſel in the form of a funnel, to prevent its ever being wetted. Above this let a long ſlender rod riſe terminating in a pointed wire, and having a ſmall wire twiſted round its whole length, to conduct the electricity the better to the funnel. From the funnel, let a wire deſcend along the building about a foot diſtance from it, and be conducted through an open ſaſh into any room which ſhall be moſt convenient for managing the experiments. In this room let a proper conductor be inſulated and connected with the wire coming in at the window. This wire and conductor, being completely inſulated, will be electrified whenever there is a conſiderable quantity of electricity in the air; and notice will be given when it is

properly

properly charged, either by the mutual repulſion of two ſmall balls of cork hung to it by threads, or by the ringing of two ſmall bells, the one ſuſpended from, and communicating with the conductor, and the other uninſulated: theſe bells will be in oppoſite ſtates of electricity when the conductor is electrified, and if a clapper or ſmall metallic ball be hung by a ſilk thread between them, it will be alternately attracted and repelled by each, and conſequently indicate the electricity of the conductor by ringing. The condenſer w
(311, K) is of excellent uſe to aſcertain the preſence and quality of atmoſpherical electricity when the conductor is too ſlightly electrified to attract a thread, or to exhibit any of the uſual appearances.

To make theſe experiments in perfect ſafety, the x
electrified wire ſhould be brought within a few inches of a conducting rod, which ſerves to guard the houſe, that the redundant electricity may paſs off that way, without ſtriking any perſon who may happen to ſtand near it. The conductor to guard the houſe ſhould conſiſt of a rod, without breaks or diſcontinuities, between one fourth and one half of an inch thick, if it be of iron, but ſmaller if it be braſs or copper, terminating upwards in a ſharp point about four or five feet above the higheſt part of the building: it is convenient that this point be of gold, or gilt, to preſerve it from ruſting. The lower end of the rod ſhould, if poſſible, be continued to ſome well or running water, or otherwiſe it ſhould be ſunk ſeveral feet into the ground, at the diſtance of ſome yards from the building. It is of

no confequence how many bendings are made in the rod, but it is much better to faften it to the outfide than the infide of the building; for thefe conductors are known to emit fparks during thunder-ftorms, notwithftanding their infertion into the earth, from which fatal confequences may be apprehended when the electric force is very great.

y It is clear, from many inftances, that the lights which are feen at the maft-heads of fhips, and on the vanes of fome churches during thunder, owe their origin to the electric matter paffing by means of uninfulated points.

z The polarity of the compafs-needle has been known, in feveral inftances, to have been deftroyed or reverfed by lightning. An effect which, as has been obferved, may be produced by the electric fhock from glafs (307, v).

A If the electrician be defirous of making experiments upon the electricity of the atmofphere to greater exactnefs, he muft raife a kite, by means of a ftring in which a fmall wire is twifted. The lower extremity of this line muft be filk, and the wire muft terminate in fome metallic conductor of fuch a form as fhall be thought moft convenient. But it is dangerous to raife it upon the approach of a thunder-ftorm; and upon this occafion the common apparatus for drawing electricity from clouds will probably anfwer every intended purpofe.

## CHAP. VIII.

### OF LIGHTNING, AND OTHER METEORS.

To know that lightning and the electric matter are B
the ſame, is a great ſtep in natural philoſophy, but we
muſt ſtill remain ignorant of the cauſes of many of the
appearances which accompany lightning, ſo long as our
acquaintance with the properties of electricity is ſo
very imperfect. We know that the clouds are almoſt C
always electrified, ſometimes poſitively, and ſometimes
negatively; but whence, or by what means, they ac-
quire this ſtate; whether by the heating or cooling D
of the air, upon the tourmalin principle, whatever that
may be, or whether the clouds be only the conductors E
by which the electric matter is conveyed through the
air, from places in the earth where it is redundant, to
other places where there is a deficiency, cannot eaſily
be determined. The firſt is the conjecture of the well
known Mr. Canton; and the latter is the chief propo-
ſition in the theory of that great philoſopher Sig.
Beccaria of Turin. It is probable, that both circum-
ſtances may conduce to the effect; the heating or
cooling of the air may produce, or rather collect, that
electricity, which is ſo great an agent in atmoſpherical
events; and its diſcharge may be effected in the man-
ner in which Signor Beccaria has, with great probabi-
lity, ſuppoſed it to be accompliſhed.

The

F The diſcovery of Sig. Volta, of the electricity of vapors, or elaſtic matter raiſed into the atmoſphere by fire or otherwiſe, is a capital advance towards the perfect knowledge of the cauſe of the electric ſtate of clouds, miſts, and the like. For vapors, carying off a larger portion of electricity than when in the fluid ſtate, muſt conſtantly give out a part of the ſame (319, D) when they arrive in the ſuperior and colder regions of the air, where they become more condenſed and form clouds. Clouds and rain will therefore naturally have the poſitive electricity, though a cloud, when once formed, may, by its influence on neighbouring clouds, cauſe them to become negative (294), by imparting not only their natural ſurplus, but even more to the earth.

G A thunder-ſtorm uſually happens in calm weather. A dark cloud is obſerved to attract others to it, by which it continually increaſes in magnitude and apparent denſity. When the cloud is thus grown to a great ſize, its lower ſurface ſwells in particular parts towards the earth, ſometimes by light flimſy clouds, and ſometimes by an inferior protuberance. During the time that the cloud is thus forming, flaſhes of lightning are ſeen to dart from one part of it to the other, and often to illuminate the whole maſs: and ſmall clouds are obſerved moving rapidly, and in very uncertain directions beneath it. When the cloud has acquired a ſufficient extent, the lightning ſtrikes the earth in two oppoſite places; the path of the lightning lying through the whole body of the cloud and its branches.

That

That thunder-clouds frequently do nothing more than conduct the electric matter from one place to another, is not only probable, on account of the matter's ſtriking in two places, but likewiſe from the conſideration, that the emiſſion of the flaſh would deſtroy the electric ſtate of the clouds, if it were not immediately recruited from ſome other part. But the electric ſtate is not deſtroyed after a flaſh, if we may judge either from the electric apparatus, or from the cloud itſelf; for the firſt appears to be not leſs electrified, and the latter is the next moment ready to make as great a diſcharge as before. Beſides, if the two flaſhes of lightning, which ſtrike at different places, nearly at the ſame time, were ſimple, ſimilar, and independent diſcharges of the cloud, why ſhould they reſemble each other? and yet they do very much, as appears by obſerving a thunder-ſtorm at a diſtance. Then it is ſeen, that if one part of the cloud give a ſingle flaſh, the other extremity will give, or rather receive, a ſingle flaſh a ſhort time or the inſtant after; but if it give two, three, or four quick ſucceſſive flaſhes, the other extremity will receive a like number a little, but very perceptible time after. The angular diſtance between the places of theſe correſpondent flaſhes is frequently four or five points of the compaſs.

It is remarkable, that moſt detached clouds, the angular heights of which are but ſmall, and which conſequently may be viewed in profile, are variouſly arched at their upper ſurface, while their under ſurface, is horizontal. This appearance is particularly obſervable in thunder-clouds, and alſo takes place in the ſmoke of

reſin,

resin, or steam of water, electrified by the common machine.

K Whatever may be the cause that disturbs the equilibrium of the electric matter in the atmosphere, it may easily be conceived, that when such disturbance happens in the upper, and highly rarefied regions of the air, the equilibrium will be restored by dartings and electric coruscations through the vacuum, similar to those exhibited in the vacuum of the air-pump. This consideration accounts for the aurora borealis, which has commonly a motion of darting or undulating between two opposite parts of the heavens.

L In clear and calm weather, when the electricity is not very strong, it may pass through the air without bringing any great quantity of vapours into its course; and, according to the conductors it meets in the air, it will sometimes be rendered visible for small parts of its passage, and occasion those appearances which we call shooting-stars. It is observable, that shooting-stars, seen at any time, in general all direct their course the same way.

M The balls of* fire, as well as the shooting-stars, occasionally seen in the air, seem to be masses of electricity, at so great a distance that their angular velocity is not sufficient to prevent the eye from discerning their shape. It is probable that every electric spark or flash of lightning consists of one or more balls of fire, though their

* Dr. Blagden has given a valuable statement of facts and deductions respecting meteors of this kind in the Phil. Trans. vol. 74.

extreme

extreme velocity presents them to the eye under the form of a line or lines (1. 259, o).

The ignis fatuus, or Will-with-the-wisp, is a lumi- N
nous meteor that seldom appears more than six feet above the ground. It is found chiefly about bogs, and is always in motion, varying both its figure and situation in a very uncertain manner. In the plains in the territory of Bologna, they are frequently very large, and give a light equal to a torch; and there are some places where a person may be almost sure of seeing them every dark night. It has been conjectured that these meteors consist of inflammable air, which has been kindled by electricity.

It was observed of water-spouts, that the conver- O
gence of winds and their consequent whirling motion, was a principal cause in producing that effect (63, L); but there are appearances which can hardly be solved by supposing this to be the only cause. They often vanish, and presently appear again in the same place: whitish or yellowish flames have sometimes been seen moving with prodigious swiftness about them, and whirlwinds are observed to electrify the apparatus very strongly. The time of their appearance is generally those months which are peculiarly subject to thunder-storms, and they are commonly preceded, accompanied, or followed by lightning, the previous state of the air being alike in both cases. And the long established custom, which the sailors have, of presenting sharp swords to disperse them, is no inconsiderable circumstance in favour of the supposition of their being electrical phenomena. Perhaps the ascending motion of the

air, by which the whirling is produced, may be the current known to issue from electrified points, as the form of the protuberance in the sea is somewhat pointed; and the electrified drop of water, heretofore mentioned, may afford considerable light in explaining this appearance.

It is extremely probable, that earthquakes owe their origin to the discharge between a cloud and the earth, in a highly electric state, or even between two clouds. They happen most frequently in dry and hot countries, which are most subject to lightning and other electrical phenomena; and are even foretold by the electric coruscations and other appearances in the air, for some days preceding the event. Earthquakes are attended by no fire, vapour, or smell, which however could hardly fail to appear, if the common opinion, of their being occasioned by a subterraneous explosion, were true. The effect of an explosion of this nature would be a gradual lifting of the earth, after which it would fall again, and, no doubt, destroy or change the course of springs, and considerably alter the face of the country: the contrary to all which is true; for, as far as observation can determine, the shock of an earthquake is instantaneous to the greatest distances, and seldom does more mischief than overthrowing buildings. Earthquakes are usually accompanied by rain, and sometimes by the most dreadful thunder-storms. All these, and many more circumstances, but especially the almost instantaneous motion of the shock, induce us to look for their cause in electricity, the only power in nature that acknowledges

acknowledges no ſenſible tranſition of time in its operations.

Dr. Prieſtley, in his Hiſtory of Electricity, has given an abridgment of Dr. Stukely's obſervations and inferences on this ſubject, and has himſelf ſhewn, by experiment, that the electric ſhock cauſes a vibration ſimilar to that of an earthquake, when it paſſes at or near the ſurfaces of bodies.

It may be here obſerved, that the knowledge we have of the properties of electricity has been acquired, for the greater part, within the laſt half century; and that if diſcoveries proceed as rapidly as they have begun, it may be hoped, that a ſimilar period will afford a more perfect acquaintance with the influence of electricity not only on atmoſpherical events, but likewiſe on magnetiſm, vegetation, muſcular motion, and other appearances, in which it is more than probable, this great and active power has a ſhare.

# BOOK III.

## SECT. IV.

## Concerning Galvaniſm.

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### CHAP. I.

DISCOVERY OF GALVANISM: METHOD OF MAKING EXPERIMENTS: VOLTA'S PILE: RESEMBLANCE BETWEEN GALVANISM AND ELECTRICITY.

A The influence generally called galvaniſm was accidentally diſcovered by Mr. Galvani, profeſſor of anatomy at Bologna, about twelve or fourteen years ago, when engaged in a ſet of experiments, the object of which was to demonſtrate the dependence of muſcu-
B lar motion on electricity. In the courſe of his inveſtigation he had met with ſeveral new and ſtriking appearances, which were certainly electrical; and one day, being employed in diſſecting a frog in a room where ſome of his friends were amuſing themſelves with electrical experiments, one of them having happened to draw a ſpark from the conductor at the ſame time that the knife touched one of the nerves of the animal, the whole body of the frog was agitated by a violent con-

vulſion.

vulsion. To assure himself that this was not the effect of mechanical irritation, he pricked the nerve with the point of the knife, but no movement ensued. He found too, that if he held the knife by its ivory handle while the spark was taken, the blade being in contact with the nerve, no convulsion was excited; but that the effect was uniformly produced, if he used an instrument entirely of metal.

From other phenomena that occurred, the professor C
was led to lay bare a portion of a large nerve leading to one of the limbs, and place the end of the bare nerve farthest from the limb on a bit of zinc. He then touched the limb with one end of a bent probe, while the other was in contact with the zinc, and thus he occasioned strong convulsive movements in the limb. If he touched either the bare nerve or the muscle, with the silver, while the zinc was in contact with the nerve, no motion ensued, unless the two metals were made to touch each other.

If a frog be divided into two portions through the D
middle by a pair of scissars, the upper part and viscera removed, the lower extremities skinned, and the inferior part of the spine also cut away, leaving only a portion attached to the sciatic nerves, which rise very high up, it will be in a very proper state for galvanic experiments. When thus prepared, the remaining portion of the spine and upper part of the sciatic nerves may be placed on a plate of zinc, Z. fig. 181, and the feet on a piece of silver, S; if then a communication be made between the two metals by a metallic conductor, C, the muscles of the frog, F, will be convulsed.

E On ſome occaſions it may be more convenient, to coat the nerve with a bit of tin foil, and the muſcle with a bit of ſilver: but it is requiſite, that two different metals be employed; and it is believed that their power
F of acting is in the following order, zinc, tin, lead, in conjunction with gold, ſilver, molybdena, ſteel, copper. On this point however authors are not agreed.

G Thus the proceſs by which theſe ſingular phenomena are produced conſiſts in effecting, by the uſe of the exciting apparatus, a mutual communication between any two points of contact, more or leſs diſtant from each other, in a ſyſtem of nervous and muſcular organs. The ſphere of this mutual communication may be regarded as a complete circle, divided into two parts. That part of it which conſiſts of the organs of the animal under the experiment has been called the animal arc; that which is formed by the metals, or galvanic apparatus, the excitatory arc.

H It has been aſſerted, that the animal arc may conſiſt either of nerves and muſcles together, or of nerves alone without muſcles; for the contraction of the muſcle has been excited, if the galvanic apparatus have been made to communicate with two diſtant parts of the nerve only, without touching the muſcle. But in this caſe the nerve appears to have acted as a conductor only by means of its moiſture, for if it be wiped quite dry the experiment will not ſucceed, though it will even in this ſtate when a communication is made with the muſcle directly.

I It is not neceſſary, that the parts of the animal arc ſhould be continuous; their contiguity is ſufficient. Neither

Neither does any difference of its parts prevent its action; for though it be composed of different parts of the same animal, or of different animals, provided these parts be in contact they are capable of conveying the galvanic influence. And even if the animal arc be interrupted, provided a communication be established between its parts by means of some conducting substance, the galvanic influence will still act.

The muscular organs, that indicate by contractions the presence of the galvanic influence, are always those in which the nerves of a complete animal arc have their termination. When all the nerves of the animal arc originate toward one of its extremities, only those muscles which correspond with the opposite extremity are susceptible of the galvanic irritation. But when an animal arc consists of more than one system of different nerves, all of which have their origin about the middle of the arc, the muscles of these several systems of nerves will be moved alike at both the extremities of the arc. K

The excitatory arc is usually formed of three different pieces at least, made of different metals. Of these three pieces one must be in contact with the nerve, one with the muscle, and the third must form the communication between the two. This in general will be found the most convenient mode, but the third piece is not absolutely necessary; for the effect will take place, if the first and second pieces be brought directly into contact, without the intervention of the third. L

The excitatory arc possesses the greatest power, when it is composed of at least three distinct pieces, each of a peculiar nature; the metals, water, or humid substances, saline solutions, carbonaceous matters, and ani- M

mal fubftances ftripped of the epidermis, being the only materials out of which thefe pieces may be formed. A fingle metal has been found capable of acting as an excitatory arc, but in fuch cafes its perfect homogeneity has been queftioned; for the flighteft alteration of a metal by alloy, or even by friction with fome other fubftance, is faid to be fufficient to render it active, though previoufly inert. Even charcoal alone may be rendered active by friction.

n The effects of galvanifm upon fome of the organs of fenfe are very ftriking. If two pieces of different metals be placed one under the tongue, and the other upon it, on bringing the two metals into contact a peculiar fenfation or tafte will be excited in the tongue. With fome of the metals this is fcarcely perceptible, but with zinc and gold, zinc and filver, or zinc and molybdena, it is very ftrong and difagreeable. The fenfation is ftrongeft when the zinc is placed upon the tongue; and it is moft diftinct when the tongue is of the common temperature, and the metals of the fame temperature with the tongue; the effect being much leffened by any confiderable increafe or diminution of heat in either. The metals fhould remain a little time in contact with the tongue, before they are made to touch each other, that the tafte of the metals may not be confounded with the fenfation produced.

o If a bar of zinc and one of filver be applied to the roof of the mouth as far back as poffible, the irritations produced by bringing their outer extremities into contact are very ftrong, and that occafioned by the zinc

p refembles tafte. Volta found, that if a tin cup, filled with

with an alcaline liquor, be held in one or both hands previously wetted with water, and the tip of the tongue be dipped in the liquor, an acid taste is perceived. He likewise found, that if a cup of tin or zinc filled with water were placed on a silver stand, and the tongue applied to the water, it was perfectly insipid, till he laid hold of the silver stand with one of his hands well wetted, when he perceived a distinct and strong acid taste.

If one of the metals be applied to the tongue, and the other to the ball of the eye, a pale luminous flash is perceived when they are brought into contact with each other, and the sensation resembling taste is at the same time produced in the tongue. A flash is in like manner produced when one of the metals is applied to the eye, and the other to any part of the palate, fauces, or inside of the cheek. This experiment requires attention; care must be taken not to press the metal against the eyeball; it should be cautiously introduced between the eyelids, till it touches any part of the ball; it should be suffered to remain there a little time, to accustom the parts to it, before the contact is made; and it should be finely polished, to prevent any mechanical irritation. Q

If a piece of one of the metals be placed between the gum and upper lip, as high up as possible, and another in a similar manner between the gum and lower lip, a vivid flash of light is perceived at the instant of bringing them into contact, and another on their separation. R

But the most powerful effects have been produced by the joint action of several pairs of different metals. S

 For

For this purpose any number of plates of copper or silver, and an equal number of tin, or which is better, of zinc, are to be provided. Silver or copper coins will answer the purpose. A number of pieces of pasteboard, leather, cloth, or any substance capable of retaining moisture, must likewise be ready; and these must be wetted either with simple water, or some saline solution. Of these a pile is to be formed, placing first a plate of silver, then a plate of zinc, next a piece of wet pasteboard, and so on alternately, finishing the pile with a plate of zinc. It will be convenient to have a frame of a proper size, resembling the frame of an hour glass, to steady the pile, as represented fig. 176, where A is the top of the frame, B the bottom, C E D three uprights of varnished wood or of glass, F G the pile, F being the silver end, G the zinc. This is commonly called Volta's pile, from the inventor.

T A pile thus made, as long as the interposed disks retain any moisture, appears to be a continued and inexhaustible source of galvanism, which permeates every conductor brought into contact with its two extremities. Thus if a person touch the top of the pile with one of his hands, and the bottom with the other, both hands being previously wetted, he will receive a smart shock, proportionate to the magnitude of the pile. With twenty pieces the shock is felt in the arms, with a hundred in the shoulders.

U A more convenient mode of forming a galvanic battery was invented by Mr. Cruickshank. This consists of a trough of hard baked mahogany about thirty inches long, in the sides and bottom of which fifty grooves are cut at equal distances. Into these are cemented

mented the metallic plates, each of which conſiſts of a plate of zinc and another of copper, of ſuch a ſize as to fit the trough, ſoldered together with ſoft ſolder at the edges, the ſolder reaching about a quarter of an inch in. All theſe plates muſt be placed in the ſame order, ſo that the copper ſide of one muſt face the zinc ſide of another throughout. When theſe are ſo cemented in as to prevent any fluid from paſſing out of one cell into another, nothing more is requiſite, than to pour in ſome fluid, and the battery is ready for uſe. It has been found, that thoſe fluids produce the moſt powerful effects, the chemical action of which on the zinc is greateſt. One part of nitric acid with twenty of water forms a very active mixture; but it is expenſive, and evolves nitrous gas, which is injurious to the lungs. Sulphuric acid with water diſengages ſuch quantities of hidrogen gas as to be very troubleſome, and ſometimes looſens the cement. Muriatic acid, in the proportion of an ounce to about a pint of water, is preferable to either. Every time the trough is uſed, it ſhould be well rinſed with clean water before it is put away, and the acid liquor may be preſerved to uſe again ſeveral times.

If a greater power than that of one trough be required, two or more may be connected together by a metallic conductor paſſing from one to the other. A ſlip of copper ſheeting, about half the width of the trough, anſwers this purpoſe very well.

With the galvanic battery thus conſtructed, either in the form of the pile or the trough, the uſual effects of the electric fluid may be obtained. Not only may the

ſhock be given, (342, T) but metals deflagrated, and water decompoſed. If the communication between

Y the two ends of the apparatus be made by two copper wires, the oppoſite extremities of which terminate in a ſmall tube filled with water, forming the centre of the conductor, hidrogen will be produced in the water at the point of the wire that communicates with the ſilver end of the pile, and the point of the wire that communicates with the zinc end will be oxided. If wires of platina be uſed, hidrogen will be evolved as before at the wire communicating with the ſilver, and oxigen at the other wire. In theſe experiments the electric ſpark is diſtinctly viſible.

Z Mr. Davy found, that, if the wires terminated in two ſeparate glaſſes of water, and he eſtabliſhed a communication between the two glaſſes with his fingers, the gaſſes were evolved as before, hidrogen from the one portion of water, and oxigen from the other. He likewiſe found, that if the ends of the pile were made to communicate with two glaſſes of water by means of muſcular fibre, and the glaſſes were connected by a ſilver wire, the effects of the pile were reverſed, hidrogen being diſengaged in the glaſs communicating with the zinc end, and the wire in the glaſs communicating with the ſilver end being oxided.

A If a piece of gold or ſilver leaf, or tin foil, be fixed to one end of the wire of communication, the other end being in contact with the ſilver end of the pile, the leaf will deflagrate as ſoon as it is brought into contact with the zinc. Finely drawn wires may be burned in the ſame way.

It

It is obſervable, that a few pairs of large plates B
operate more powerfully in deflagrating metals, than the ſame extent of ſurface forming a higher and proportionally more ſlender pile, while the latter gives the ſtronger ſhock.

The pile is likewiſe capable of charging a jar, or a C
battery, and ſometimes by momentary contact; and the battery will then give a ſhock preciſely as if charged to the ſame degree by an electrical machine; but the pile will not increaſe the charge of a battery by repeated contacts, as the electrical machine does by repeated revolutions.

To excite the galvanic influence, however, it is not D
abſolutely neceſſary, that two metals be employed. For example a pile may be formed of a plate of metal, cloth ſoaked in dilute nitrous acid, cloth ſoaked in water, cloth ſoaked in a ſolution of ſulphuret of potaſh, then a plate of the ſame metal followed by cloths ſimilarly wetted and in the ſame order, and ſo on alternately. In this way ſilver, copper, zinc, and lead, have been ſeparately and ſucceſsfully tried. If a trough be uſed, the ſeparation between the acid and ſulphuret may be made by a plate of horn, and the two fluids may be connected by a ſlip of wetted paper hung over the edge of the horn, which will not cauſe the fluids to mix, becauſe water is lighter than either.

Another experiment of Mr. Davy's ſhows the direct E
efficacy of the fluid in this apparatus, as in it the ſame galvanic power is made to move either from the top or bottom of a pile of two metals, according to the nature of the interpoſed fluid. If a pile of copper and

iron be conſtructed as uſual, with water interpoſed, the iron will be in the poſitive ſtate, the copper in the negative: on the contrary, if a ſolution of ſulphuret of potaſh be uſed inſtead of water, the iron will be negative, the copper poſitive. In the former caſe the iron is oxided, in the latter the copper.

F Farther, with two different fluids and well burned charcoal a pile may be conſtructed, without any metal. If two glaſſes, one containing water, or ſolution of ſulphuret of potaſh, the other nitric or ſulphuric acid, be connected by a piece of charcoal of a proper ſhape to dip into the two fluids, or by two long thin ſlips of charcoal tied together with ſilk ſo as to form an angle, a galvanic combination will be formed; as will be found by its agency on the limbs of frogs, or its effects on the organs of ſenſe, when the circle is completed.

G A battery may be conſtructed of a number of ſeries of this kind, by connecting the fluids alternately with charcoal and with moiſtened cloth; and if denſe charcoal, ſuch as that of box or lignum vitæ, concentrated nitric acid, and a ſolution of ſulphuret of potaſh be employed, its power appears to be ſuperior to that of copper with the ſame fluid elements, and nearly equal to that of a pile of zinc, ſilver, and water.

H Galvaniſm likewiſe develops itſelf in a powerful manner, independently of metals, by means of the human animal machine. If you hold in your hand moiſtened with ſalt water, the muſcles of a prepared frog, and apply the crural nerves to the tip of your tongue, you will immediately ſee violent contractions produced

produced in the frog: and all ſuſpicion of any ſtimulant exerting an action in this caſe may be removed by repeating the experiment with the frog held in the dry hand, as the muſcular contractions will then ceaſe, unleſs the action of galvaniſm in the frog or in the animal machine, be uncommonly powerful.

Muſcular contractions can be excited without eſta- 1
bliſhing a continued arc from the nerves to the muſcles. The legs of a prepared frog being held in the hand, and the ſpinal marrow brought near to the biceps muſcle of a criminal recently executed, the muſcle having firſt been laid bare, contractions were produced in it; but no contractions took place when the operator was inſulated. In this experiment, if any other body be made to touch the frog, it will remain motionleſs.

Neither is any intermediate body neceſſary, as gal- 2
vaniſm may be excited in the animal machine merely by the application of the nerves to the muſcles. Let the lower extremities of a prepared frog, the whole being previouſly wetted with a ſolution of common ſalt, be ſuſpended by a glaſs rod, H, fig. 182, paſſing between the nerves R, and under the part of the ſpine, S. With another glaſs rod, M, raiſe the leg, L, till the muſcles are brought into contact with the nerves at R, when convulſions will take place. Or let M N, fig. 183, repreſent a glaſs rod; A and B two prepared frogs, the feet of B being ſecured to the ſpine C of the frog A. When the ſciatic nerves E, iſſuing from the ſpine of B, are raiſed by a glaſs rod ſo as to touch the muſcles of the upper frog at A, contractions are produced in each

of

of the animals, they having been previously moistened with a strong brine as in the former case.

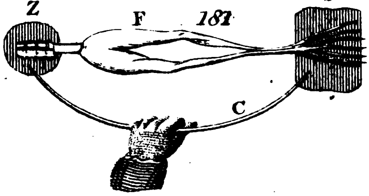
L The application of galvanism to warm blooded animals (347,1) exhibits a still more striking spectacle. Cut off the head of an ox recently killed, moisten one of the ears by injecting into it a solution of salt, connect this with one end of the pile by means of a wire introduced into it, and touch the inside of one of the nostrils with a wire that communicates with the other end of the pile; the eyes will open, the ears shake, the tongue move, and the nostrils swell, as in the living animal when irritated.

M If the arc be established between the two ears, or between one of them and the spinal marrow, or the tongue, strong movements are excited.

N These experiments may be varied in a great number of ways, by taking the head of a dog, horse, rabbit, chicken, or other animal; two heads, placed so that the parts where they were separated from the trunk are in contact; a head and trunk of the same animal, or of animals of different species, twelve inches or more distant, the table that supports them being wet with a solution of salt; or the headless trunk of an animal. Of all the heads hitherto tried, that of the horse exhibited the most violent motion.

O It is to be observed, that the muscles are affected by the action of the pile in a much more powerful manner when they are laid entirely bare, and when the arc is made to penetrate to a considerable depth in their substance. The convulsions are increased likewise in proportion

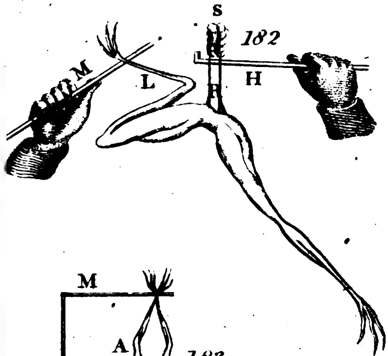
181



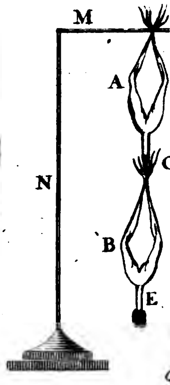

's Electrometer.

180


182



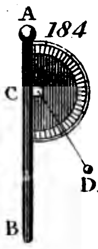

183




Electric Jar

79

184




Quadrant Electrometer.

Warner sc.

proportion to the number of points of contact between the arc and the muscle. The brain itself is capable of being agitated by the galvanic influence; but of all the muscular parts the heart appears to be least susceptible of it.

# INDEX

TO THE

## SECOND VOLUME.

### A

*Bifmuth*,

*Plumbum*

*Saturation,*

# INDEX.

## T



## U



## V



## W

T. Bensley, Printer, Bolt Court, Fleet Street, London.